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COST EFFECTIVENESS STUDY OF WASTEWATER MANAGEMENT SYSTEMS FOR SELECTED U.S. COAST GUARD VESSELS

Volume II - Effectiveness Assessment of Candidate Systems

Sidney Orbach

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New York, N.Y. 10019

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March 1977

Final Report

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PREPARED FOR

U.S. DEPARTMENT OF TRANSPORTATION

UNITED STATES COAST GUARD

OFFICE OF RESEARCH AND DEVELOPMENT

WASHINGTON, D.C. 20590

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16. Abstract

A generalized and systematic effectiveness assessment methodology, including a computer program for quantifying the effectivaness of candidate system vessel combinations was developed. The methodogy is described and guidelines for its use are presented.

The results of applying this effectiveness assessment methodology to the 18 Wastewater Management System (WMS) concepts in configurations suitable for each of the six vessels included in this study are presented.

The effectiveness model used is based on the following seven measures of effectiveness: Adaptability for Shipboard Installation, Performance, Operability, Personnel Safety, Habitability, Reliability, and Maintainability. Each effectiveness measure was successively broken down into constituent factors and subfactors, resulting in 111 individual criteria which were used as the basis for quantifying the effectiveness of each viable candidate system on each vessel. The effectiveness attribute data used are also presented.

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FINAL REPORT

For

U.S. Dept. of Transportation
U.S. Coast Guard
Office of Research and Development
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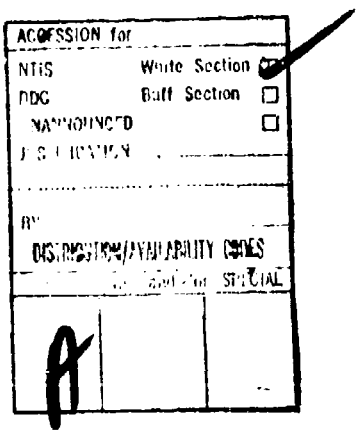
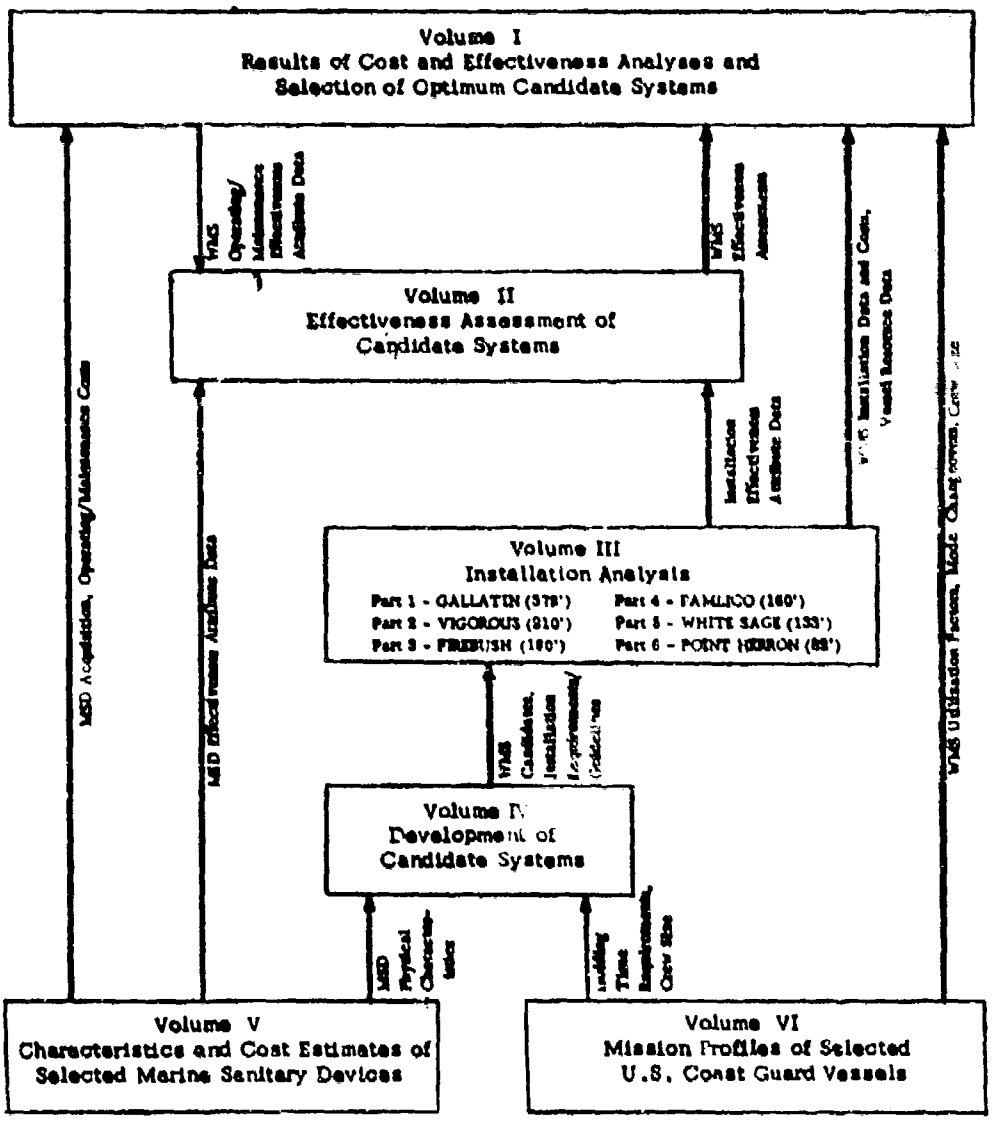


PREFACE

The relationship among the volumes of the report is depicted below. This relationship does not convey all the information contained within each volume.



SUMMARY OF CANDIDATE SYSTEM/VESSEL EFFECTIVENESS ASSESSMENTS

Vessel GALLATIN (378')

WMS No.	TYPE: Coll/Trans Subsys (Blank)	TYPE: Treatment/Disposal Subsystem: Black	TYPE: Treatment/Disposal Subsystem: Gray	Holding Capacity: Black (%)	Holding Capacity: Gray (%)	MEASURE OF EFFECTIVENESS RATINGS (AND ASSOCIATED WEIGHTS): Adapt. ability for Ship Inst. (8)	Perfor. mance (15)	Oper. ability (12)	Personnel Safety (11)	Habit. ability (17)	Reli. ability (23)	Maintain ability (23)	Overall Effectiveness (E) Rating
1	Gravity Collect.	Holding Tank	Holding Tank	100	19	88	72	91	95	75	96	92	87
2	Oil Recircul. (Chrysler)	Chrysler + Hld Tnk	Holding Tank	100	18	81	67	52	88	51	87	78	72
3		Chrysler + Incin.	Holding Tank	100	13	78	76	52	82	36	80	78	68
4	Gravity Collect. (Grumman)	Grum Flow Thru+HldTk	Holding Tank	100	17	77	70	80	94	58	85	79	77
5		Grumman Flow Thru + Holding Tank		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6	Gravity Collect.	Holding Tank	Grum Flow Thru+HldTnk	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7	Gravity Collect. (Grumman)	Grum Flow Thru+Incin.	Holding Tank	100	17	73	72	71	80	43	83	80	72
8		Grumman Flow Thru + Incinerator		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9	Vacuum Collect. (Jered)	Holding Tank	Holding Tank	100	21	72	69	65	95	71	44	53	64
10		Incinerator	Holding Tank	100	21	69	70	53	92	55	33	53	57
11		GATX Evap.	Holding Tank	100	17	65	58	64	91	65	42	41	58
12		Holding Tank	Grum Flow Thru+ Hld Tnk	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
13		Incinerator	Grum Flow Thru + Incin.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
14	M/T Pump Collect. (GATX)	Holding Tank	Holding Tank	100	30	71	70	86	93	67	76	49	72
15		Incinerator	Holding Tank	100	33	67	68	74	91	50	64	49	65
16		GATX Evap.	Holding Tank	100	17	64	60	85	89	60	74	41	67
17		Holding Tank	Grum Flow Thru+Hld Tnk	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
18		Incinerator	Grum Flow Thru + Incin.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

N/A - Not a viable candidate system/vessel combination.

SUMMARY OF CANDIDATE SYSTEM/VESSEL EFFECTIVENESS ASSESSMENTS

Vessel VIGOROUS (210')

WMS No.	TYPE: Coll/Trans Subsys (Blank)	TYPE: Treatment/Disposal Subsystem: Black	TYPE: Treatment/Disposal Subsystem: Gray	Holding Capacity: Black (%)	Holding Capacity: Gray (%)	MEASURE OF EFFECTIVENESS RATINGS (AND ASSOCIATED WEIGHTS): Adapt-ability for Ship Inst. (8)	Perfor-mance (15)	Oper-ability (12)	Personnel Safety (11)	Habit-ability (17)	Reli-ability (23)	Maintain-ability (23)	Overall Effectiveness (E) Rating
1	Gravity Collect.	Holding Tank	Holding Tank	40	1	84	58	91	95	75	95	93	84
2	Oil Recircul. (Chrysler)	Chrysler + Hld Tnk	Holding Tank	53	1	69	56	54	88	51	83	81	69
3		Chrysler + Incin.	Holding Tank	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4	Gravity Collect. (Grumman)	Grum Flow Thru+HldTk	Holding Tank	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5		Grumman Flow Thru + Holding Tank		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6	Gravity Collect.	Holding Tank	Grum Flow Thru+HldTnk	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7	Gravity Collect. (Grumman)	Grum Flow Thru+Incin	Holding Tank	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8		Grumman Flow Thru + Incinerator		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9	Vacuum Collect. (Jered.	Holding Tank	Holding Tank	48	1	65	57	65	95	71	43	50	61
10		Incinerator	Holding Tank	100	1	63	70	52	88	55	31	50	55
11		GATX Evap.	Holding Tank	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12		Holding Tank	Grum Flow Thru+Hld Tnk	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
13		Incinerator	Grum Flow Thru + Incin.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
14	M/T Pump Collect. (GATX)	Holding Tank	Holding Tank	100	1	76	69	86	93	67	80	53	74
15		Incinerator	Holding Tank	100	3	62	68	74	87	50	67	50	65
16		GATX Evap.	Holding Tank	100	1	69	60	86	89	60	79	44	69
17		Holding Tank	Grum Flow Thru+Hld Tnk	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
18		Incinerator	Grum Flow Thru + Incin.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

N/A - Not a viable candidate system/vessel combination.

SUMMARY OF CANDIDATE SYSTEM/VESSEL EFFECTIVENESS ASSESSMENTS

Vessel FIREBUSH (180')

WMS No.	TYPE: Coll/Trans Subsys (Blank)	TYPE: Treatment/Disposal Subsystem: Black	TYPE: Treatment/Disposal Subsystem: Gray	Holding Capacity: Black (%)	Holding Capacity: Gray (%)	MEASURE OF EFFECTIVENESS RATINGS (AND ASSOCIATED WEIGHTS): Adaptability for Ship Inst. (8)	Performance (15)	Operability (12)	Personnel Safety (11)	Habitability (17)	Reliability (23)	Maintainability (23)	Overall Effectiveness (E) Rating
1	Gravity Collect.	Holding Tank	Holding Tank	100	0	82	71	90	95	75	96	93	86
2	Oil Recircul. (Chrysler)	Chrysler + Hld Tnk	Holding Tank	100	0	80	67	51	88	51	82	78	71
3		Chrysler + Incin.	Holding Tank	100	12	77	75	51	82	46	77	76	69
4	Gravity Collect. (Grumman)	Grum Flow Thru+HldTk	Holding Tank	100	22	83	69	76	94	58	84	78	76
5		Grumman Flow Thru + Holding Tank		100	100	83	70	73	94	73	80	76	78
6	Gravity Collect.	Holding Tank	Grum Flow Thru+ HldTnk	100	100	81	71	73	95	60	89	76	78
7	Gravity Collect. (Grumman)	Grum Flow Thru+Incin.	Holding Tank	100	29	79	71	67	80	53	81	79	73
8		Grumman Flow Thru + Incinerator		100	100	78	75	62	72	63	76	74	71
9	Vacuum Collect. (Jered)	Holding Tank	Holding Tank	100	13	70	68	70	95	71	46	48	64
10		Incinerator	Holding Tank	100	35	59	69	59	92	65	31	47	57
11		GATX Evap.	Holding Tank	100	35	61	57	70	91	65	45	35	58
12		Holding Tank	Grum Flow Thru+ Hld Tnk	100	100	62	68	59	95	56	39	36	56
13		Incinerator	Grum Flow Thru + Incin.	100	100	59	67	52	80	63	26	37	52
14	M/T Pump Collect. (GATX)	Holding Tank	Holding Tank	100	13	67	69	82	93	67	86	60	75
15		Incinerator	Holding Tank	100	35	62	67	69	91	60	70	57	68
16		GATX Evap.	Holding Tank	100	35	60	59	82	89	60	84	52	70
17		Holding Tank	Grum Flow Thru+Hld Tnk	100	100	58	68	69	94	52	78	53	68
18		Incinera'	Grum Flow Thru + Incin.	100	100	57	68	63	80	59	66	53	64

N/A - Not a v sble candidate system/vessel combination.

SUMMARY OF CANDIDATE SYSTEM/VESSEL EFFECTIVENESS ASSESSMENTS

Vessel PAMLICO (160')

WMS No.	TYPE: Coll/Trans Subsys (Blank)	TYPE: Treatment/Disposal Subsystem: Black	TYPE: Treatment/Disposal Subsystem: Gray	Holding Capacity: Black (%)	Holding Capacity: Gray (%)	MEASURE OF EFFECTIVENESS RATINGS (AND ASSOCIATED WEIGHTS): Adapt. ability for Ship Inst. (8)	Performance (15)	Operability (12)	Personnel Safety (11)	Habitability (17)	Reliability (23)	Maintainability (23)	Overall Effectiveness (E) Rating
1	Gravity Collect.	Holding Tank	Holding Tank	100	55	55	63	87	95	75	90	84	80
2	Oil Recircul. (Chrysler)	Chrysler + Hld Tnk	Holding Tank	100	64	61	60	46	88	51	74	69	64
3		Chrysler + Incin.	Holding Tank	100	64	58	68	48	82	36	68	71	61
4	Gravity Collect. (Grumman)	Grum Flow Thru+HldTk	Holding Tank	100	64	56	61	71	94	58	73	65	68
5		Grumman Flow Thru + Holding Tank		100	100	57	66	74	94	73	68	70	72
6	Gravity Collect.	Holding Tank	Grum Flow Thru+HldTnk	100	100	57	65	74	95	60	80	70	72
7	Gravity Collect. (Grumman)	Grum Flow Thru+Incin.	Holding Tank	100	64	54	62	63	80	43	71	68	63
8		Grumman Flow Thru + Incinerator		100	100	54	71	64	72	58	65	72	65
9	Vacuum Collect. (Jered)	Holding Tank	Holding Tank	100	64	76	62	72	95	71	47	51	64
10		Incinerator	Holding Tank	100	64	73	63	62	92	55	27	50	55
11		GATX Evap.	Holding Tank	100	64	75	54	76	91	55	43	44	60
12		Holding Tank	Grum Flow Thru+Hld Tnk	100	100	74	63	60	95	56	34	37	56
13		Incinerator	Grum Flow Thru + Incin.	100	100	71	63	53	80	58	22	51	52
14	M/T Pump Collect. (GATX)	Holding Tank	Holding Tank	100	64	67	63	81	93	67	74	53	71
15		Incinerator	Holding Tank	100	64	64	61	72	91	50	54	50	61
16		GATX Evap.	Holding Tank	100	64	66	55	83	89	60	70	49	66
17		Holding Tank	Grum Flow Thru+Hld Tnk	100	100	66	64	69	94	52	51	44	63
18		Incinerator	Grum Flow Thru + Incin.	100	100	63	64	62	80	54	49	49	58

N/A - Not a viable candidate system/vessel combination.

SUMMARY OF CANDIDATE SYSTEM/VESSEL EFFECTIVENESS ASSESSMENTS

Vessel WHITE SAGE (133')

WMS No.	TYPE: Coll/Trans Subsys (Blank)	TYPE: Treatment/Disposal Subsystem: Black	TYPE: Treatment/Disposal Subsystem: Gray	Holding Capacity: Black (%)	Holding Capacity: Gray (%)	MEASURE OF EFFECTIVENESS RATINGS (AND ASSOCIATED WEIGHTS): Adapt. ability for Ship Inst. (9)	Perfor-mance (15)	Oper. ability (12)	Personnel Safety (11)	Habit. ability (17)	Reli. ability (23)	Maintain. ability (23)	Overall Effectiveness (E) rating
1	Gravity Collect.	Holding Tank	Holding Tank	100	100	95	72	87	95	75	94	86	86
2	Oil Recircul. (Chrysler)	Chrysler + Hld Tnk	Holding Tank	100	100	82	68	46	88	51	76	69	68
3		Chrysler + Incin.	Holding Tank	100	100	80	76	47	88	36	70	70	65
4	Gravity Collect. (Grumman)	Grum Flow Thru+HldTk	Holding Tank	100	100	84	70	70	94	58	80	70	74
5		Grumman Flow Thru + Holding Tank		100	100	89	69	72	94	73	74	73	76
6	Gravity Collect.	Holding Tank	Grum Flow Thru+HldTnk	100	100	88	70	71	95	60	85	71	76
7	Gravity Collect. (Grumman)	Grum Flow Thru+Incin.	Holding Tank	100	100	85	72	62	73	43	77	73	68
8		Grumman Flow Thru + Incinerator		100	100	86	74	62	60	58	71	76	69
9	Vacuum Collect. (Jered)	Holding Tank	Holding Tank	100	100	79	69	68	95	71	41	51	64
10		Incinerator	Holding Tank	100	100	72	70	58	94	55	27	50	56
11		GATX Evap.	Holding Tank	100	100	73	58	69	91	65	38	45	59
12		Holding Tank	Grum Flow Thru+ Hld Tnk	100	100	73	68	63	95	56	31	41	56
13		Incinerator	Grum Flow Thru + Incin.	100	100	69	67	49	70	58	19	53	51
14	M/T Pump Collect. (GATX)	Holding Tank	Holding Tank	100	100	76	70	80	93	67	66	49	70
15		Incinerator	Holding Tank	100	100	72	68	69	91	50	52	48	62
16		GATX Evap.	Holding Tank	100	100	74	61	81	90	60	63	47	66
17		Holding Tank	Grum Flow Thru+Hld Tnk	100	100	73	68	68	92	52	58	43	62
18		Incinerator	Grum Flow Thru + Incin.	100	100	67	67	63	69	37	44	47	54

N/A - Not a viable candidate system/vessel combination.

SUMMARY OF CANDIDATE SYSTEM/VESSEL EFFECTIVENESS ASSESSMENTS

Vessel POINT HERRON (82')

WMS No.	TYPE: Coll/Trans Subsys (Blank)	TYPE: Treatment/Disposal Subsystem: Black	TYPE: Treatment/Disposal Subsystem: Gray	Holding Capacity: Black (%)	Holding Capacity: Gray (%)	MEASURE OF EFFECTIVENESS RATINGS (AND ASSOCIATED WEIGHTS): Adapt. ability for Ship Inst. (8)	Perfor- mance (15)	Oper. ability (12)	Personnel Safety (11)	Habit. ability (17)	Reli- ability (23)	Maintain- ability (23)	Overall Effectiveness (E) Rating
1	Gravity Collect.	Holding Tank	Holding Tank	58	0	85		83	95	75	91	85	82
2	Oil Recircul. (Chrysler)	Chrysler + Hld Tnk	Holding Tank	N/A	N/A	N/A		/A	N/A	N/A	N/A	N/A	N/A
3		Chrysler + Incin.	Holding Tank	N/A	N/A	N/A		/A	N/A	N/A	N/A	N/A	N/A
4	Gravity Collect. (Grumman)	Grum Flow Thru+HldTk	Holding Tank	N/A	N/A	N/A	N/A	/A	N/A	N/A	N/A	N/A	N/A
5		Grumman Flow Thru + Holding Tank		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6	Gravity Collect.	Holding Tank	Grum Flow Thru+HldTnk	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7	Gravity Collect. (Grumman)	Grum Flow Thru+Incin.	Holding Tank	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8		Grumman Flow Thru + Incinerator		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9	Vacuum Collect. (Jered)	Holding Tank	Holding Tank	100	20	62	67	65	95	71	38	44	60
10		Incinerator	Holding Tank	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11		GATX Evap.	Holding Tank	100	20	61	57	67	90	65	36	38	56
12		Holding Tank	Grum Flow Thru+Hld Tnk	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
13		Incinerator	Grum Flow Thru + Incin.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
14	M/T Pump Collect. (GATX)	Holding Tank	Holding Tank	100	20	71	68	74	93	67	75	51	71
15		Incinerator	Holding Tank	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
16		GATX Evap.	Holding Tank	100	20	60	59	76	89	60	72	49	66
17		Holding Tank	Grum Flow Thru+Hld Tnk	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
18		Incinerator	Grum Flow Thru + Incin.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

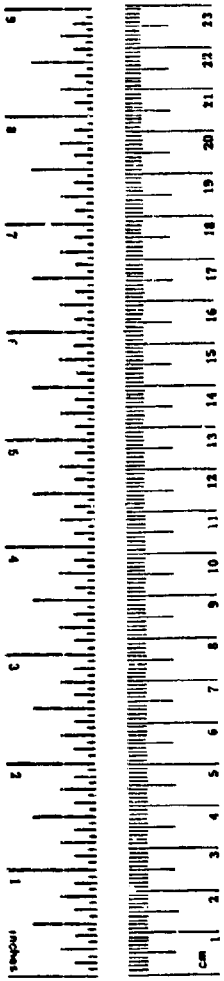
N/A - Not a viable candidate system/vessel combination.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

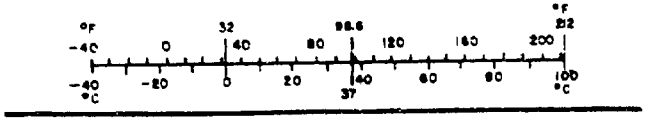
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°c

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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INTRODUCTION

OBJECTIVES

There are two main objectives of the effectiveness analysis. The first objective is the development of a generalized methodology for assessing the effectiveness of candidate system/vessel combinations. Fulfillment of this objective requires that the methodology have the following properties:

- Ability to address all issues which are considered to be pertinent to an effectiveness assessment in general, and in particular to the specific candidate systems and vessels being considered.
- Ability to accommodate both quantitative and qualitative data pertaining to candidate system/vessel combinations as well as relevant assumptions and constraints.
- Ability to accommodate subjective judgements of the decision-maker.
- Consistency between the level of detail of the analysis and data availability. This property requires that while full use should be made of all system/vessel data which is either available or can readily be made available, data which cannot be obtained within the confines of the study should not be called for.
- Ability to provide quantitative results, preferably at several levels of detail, to facilitate making comparisons and trade-offs. However, the quantitative results should be transparent to user, i.e., readily interpretable in terms of the system/vessel properties, the objectives, requirements, constraints, etc.

The second objective is the application of the effectiveness assessment methodology to the viable candidate system/vessel combinations included in this study. The results of this applicati[illegible]ould in turn be

used to study the cost versus effectiveness relationship of the candidates in order to choose an optimum, i.e., most cost-effective candidate system for each vessel class.

SCOPE OF EFFECTIVENESS ANALYSIS

The effort under this portion of the study includes the following:

- Development and documentation of a generalized effectiveness modeling and assessment methodology.
- Development and documentation of a generalized computer program for quantifying the effectiveness of candidate system/vessel combinations.
- Development of an effectiveness model suitable for analyzing candidate wastewater management systems (WMS) for selected U.S. Coast Guard vessels. The candidate systems are intended for managing the black (output from commodes, urinals and garbage grinder) and gray (galley and turbid, i.e., output from sinks, showers, laundry, deck, drains, etc.) wastewaters aboard the vessels.
- Development and documentation of the effectiveness attribute data required as input to the effectiveness model.
- Exercise the effectiveness model by substituting the data and developing quantitative effectiveness assessments for all viable candidate system/vessel combinations.

Systems and Vessels Analyzed

The systems and vessels considered for the effectiveness quantification are the 18 WMS concepts in configurations suitable for each of the six vessels included in this study (see Volume IV). Of these, effectiveness attribute data were developed and results obtained only for those system/vessel combinations which were judged to be viable candidates on the basis of the installation analysis (see Volume III).

General Applicability of the Effectiveness Assessment Methodology

Although specific results were obtained for the viable candidate system/vessel combinations included in this study, both the concepts and the procedural steps of the effectiveness modeling and quantification methodology developed as part of this study are general and have wide applicability. Specifically, this methodology is applicable to any type of problem which can be cast in the context of choosing an optimum (i.e., most cost-effective) candidate from a number of available legitimate alternatives. These alternative candidates do not necessarily have to be systems. Thus, the candidates may be alternative choices of processes or (e.g., chemical), alternative approaches to solving a problem, etc.

Furthermore, the computer program for quantifying effectiveness was not written for any one specific effectiveness model. Instead, the effectiveness model (and its associated data) are part of the input. As a result, this computer program is capable of handling any type of problem as soon as the necessary inputs have been developed.

Limitations

The effectiveness ratings presented herein are applicable to the specific systems and vessels included in this study. Furthermore, these results reflect the assumptions, objectives, requirements and constraints which are part of the context of this study. As a result, caution is advised in attempting to use these results directly for systems and/or vessels others than those specifically included in this study, or in a different context.

The effectiveness ratings are subject to the following considerations. The effectiveness attributes used as the basis for the ratings are a mixture of objectively determined system/vessel characteristics as well as subjectively determined qualitative system/vessel characteristics based on the analysis of the marine sanitary devices (MSDs) and the candidate WMS systems which we hybridized from these MSD subsystems. (see data in Volumes I, III and V).

In addition, the elements of the effectiveness model, especially the weight assignment and the effectiveness rating functions are based on subjective judgements. As a result, if one agrees with these judgements as well as the data used, then one may also accept the validity of the results. On the other hand, if one has reservations about the accuracy of the data and/or strongly disagrees with the subjective judgements inherent in the effectiveness model, then one may question the validity of the results. In such cases, one can substitute different data and/or subjective judgements, assumptions, etc., and obtain a new set of results (at least in principle, even if one may not actually wish to do this). In either case, the data, the subjective judgements, the assumptions, etc., used are all documented and are accessible. Another relevant point to keep in mind is that the effectiveness ratings are not to be used in an absolute sense but rather as a means of comparing candidate systems for the purpose of discerning differences among the alternatives available. In this connection, it is noted that since the same effectiveness model is used to assess the candidate systems and the same generic MSD subsystem/equipment data is used for all system/vessel combinations, all candidates are treated equally. Hence, bias (to be distinguished from subjective judgement) in the results is avoided.

ASSUMPTIONS

The assumptions which govern the effectiveness analysis of the candidate system/vessel combinations are primarily those which were used in the development of the effectiveness attribute data and the development of the effectiveness model. The assumptions pertaining to the effectiveness attribute data are documented in Volumes V and III for the MSD effectiveness attribute data and for the WMS installation effectiveness attribute data, respectively. Assumptions pertinent to the effectiveness model are primarily those used in the development of the effectiveness rating functions (ERFs) and appear as part of the ERF documentation.

APPROACH

The approach used in the development of the effectiveness analysis methodology and its application to the candidate system/vessels combinations included in this study is discussed briefly below.

Development of the Effectiveness Assessment Methodology

The basic concepts which form the basis of this effectiveness assessment methodology are not new and there are a number of precedents for their use. A prior application* of these concepts might be described as the development of the underlying philosophy and theory of the approach to the status of an art. The main objective of this effort was a refinement of this effectiveness analysis approach and additional development (and documentation) of the procedural aspects of the approach, leading to a general and well defined methodology with clearly identifiable steps.

The effectiveness assessment methodology is the system of analysis techniques and associated computational procedures which start with the relevant information concerning the candidates and their associated context as an input, and generated quantitative effectiveness ratings as an output. This methodology consists of procedures, guidelines and computational aids for executing the following three main steps of the effectiveness assessment.

- Development of the effectiveness model
- Development of effectiveness attribute data geared to the effectiveness model.
- Quantification of effectiveness.

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* S. Orbach and R. Field, "Cost Effectiveness Study of Selected Marine Sanitary Devices; Effectiveness Assessment," Phase II Final Report, NSRDC Report 4426, September 1974, Contract N00600-72-D-0613, Conducted by Bradford National Corporation and NSRDC.

The development of the effectiveness model consists of the following identifiable steps:

- Selection of a set of measures of effectiveness (M/Es). The M/Es constitute a set of highest level overall criteria which will be the basis for assessing the effectiveness of the candidates.
- Assignment of M/E weights. These M/E weights are used to indicate the importance of each M/E in relation to the others.
- Determination of the factors and subfactors of each M/E. Factors result from a breakdown of an M/E into its constituent lower level subordinate criteria which are implied by the higher level criterion represented by the given M/E. Subfactors result from a breakdown of a factor or another subfactor into its constituent lower level subordinate criteria which are implied by the higher level criterion represented by the given factor or subfactor. Elementary factors or subfactors are those which have no subordinate subfactors and which can be directly related to one or more attributes of the candidates under consideration.
- Assignment of factor/subfactor weights. These weights are used to indicate the importance of each factor/subfactor (i.e., criterion) in relation to the others at the same level of subordination.
- Development of an effectiveness rating function (ERF) for every elementary factor/subfactor. An ERF constitutes a functional relationship between the candidate attribute (characteristic) relevant to the given elementary factor/subfactor and an effectiveness rating which is a quantitative measure of the candidate's acceptability, quality, worth, etc., with respect to the given criterion. The ERFs constitute an important element of the effectiveness model. They provide a mechanism for systematically bringing together and integrating the essential elements of the effectiveness assessment, namely:

.. Assumptions, goals, requirements and constraints.

.. Technical information

.. Subjective judgements of the decision maker

The effectiveness attribute data required is determined by the ERFs. The ERFs also determine the format of these data and a numbering scheme which uniquely identifies each ERF within each M/E is used to associate the data with the corresponding ERF. An important aspect of the development of the ERFs and the associated effectiveness attribute data is its flexibility with respect to the type and level of detail of the required data. This ensures that the data requirements are realistic and are consistent with common practice in the field, i.e., the analyses performed in support of the effectiveness assessment such as MSD analysis, installation analysis, life cycle cost analysis, etc. Thus, the development of effectiveness attribute data represents another important mechanism for integrating the results of the various analyses which are normally performed in the course of studying the candidates.

The quantification of the effectiveness is accomplished by relating the rating at any level of subordination in the effectiveness model to the next lower level elements of the model as the sum of products of the ratings and associated weights of these elements. Thus, starting with the elementary factors/subfactors, the next higher level subfactor or factor ratings are given as the sum of products of the elementary factors/subfactors. Similarly, the rating for a given M/E is obtained as the sum of products of its factor ratings and their associated weights. Finally, the overall effectiveness rating is obtained as the sum of the products of M/E ratings and their associated weights. Once the effectiveness model and the associated effectiveness attribute data have been developed, the quantification of effectiveness is fairly straightforward and is accomplished by a computer program. The output of the computer program consists of an overall effectiveness rating for each candidate as well as effectiveness ratings with respect to each M/E.

As part of the development of the effectiveness assessment methodology, the above steps have been documented in greater detail and guidelines for executing these steps have been included (see "Discussion of the Effectiveness Assessment Methodology and Application Guidelines"). A summary of the methodology is presented in Figure 1 which shows the three main steps of the procedure namely, development of the model, use of effectiveness attribute data and quantification of effectiveness. It is noted both from the previous discussion of the development of the elements of the effectiveness model and from Figure 1 that the M/Es, the factor/subfactors and their associated levels of subordination constitute a hierarchy. Actually, four types of hierarchies can be discerned in connection with the effectiveness assessment methodology, namely:

- A hierarchy of objectives and requirements.
- A hierarchy of criteria associated with the objectives and requirements.
- A hierarchy indicating the importance of each criterion in relation to the others.
- A hierarchy of effectiveness ratings which are quantitative measures of the degree to which each criterion in the hierarchy is satisfied by each candidate.

The first three hierarchies are associated with the effectiveness model and the last hierarchy is associated with the quantification of effectiveness. However, it is noted from Figure 1 that the quantification of effectiveness includes the use of the weights. Thus, the weights possess a dual character, namely, as indicators of the importance of the relative importance of each criterion (related to the effectiveness model), and as numbers used in obtaining the ratings (related to the quantification process). Finally, it is noted that the development of the effectiveness

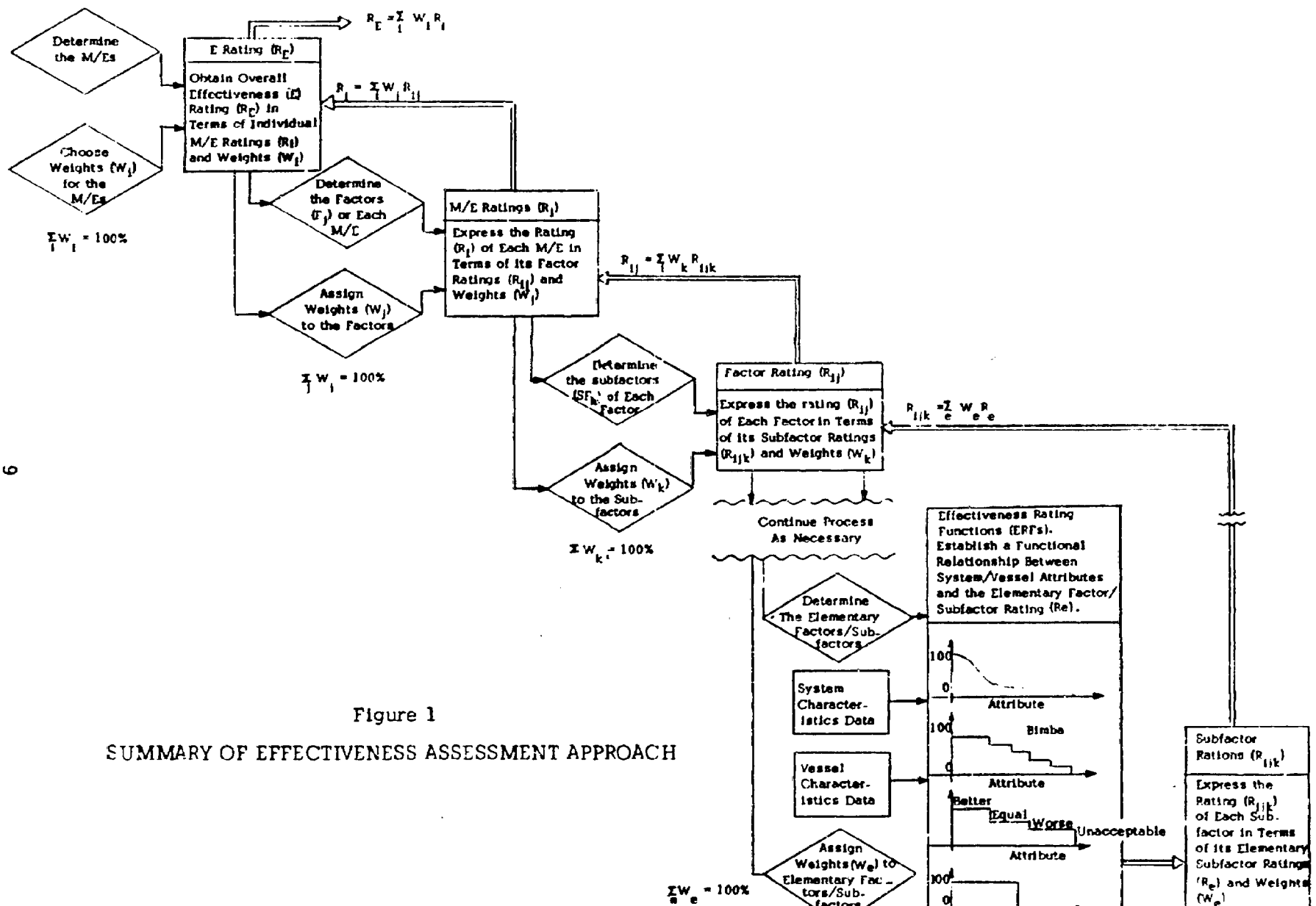
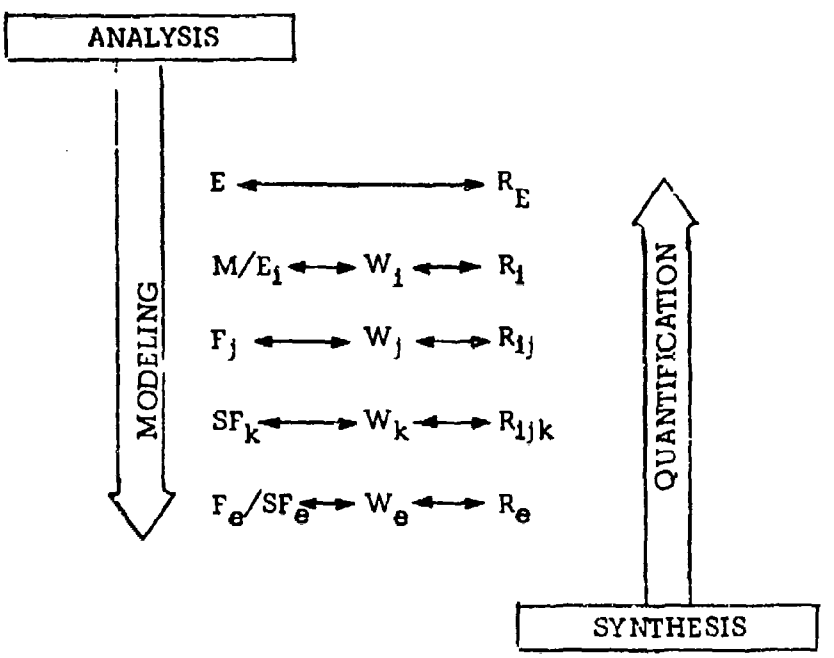


Figure 1

SUMMARY OF EFFECTIVENESS ASSESSMENT APPROACH

model can be characterized as analysis (top to bottom processes), whereas the quantification of effectiveness can be characterized as synthesis (bottom to top process). The above discussed relationships in connection with the effectiveness assessment methodology are summarized below.



Development of the Computer Program for Quantifying Effectiveness

Although the quantification of effectiveness is essentially a straightforward computational procedure, the magnitude of the calculations is such that it is impractical to attempt this manually. As a result, a computer program was developed in order to perform these calculations

rapid and accurately. An important feature of the computer program is that is was not developed for any specific effectiveness model. Instead, the effectiveness model* (and its associated data) is an input to the program. Thus, this computer program is general and applicable to a wide range of problems, and constitutes an essential element of the effectiveness assessment methodology.

Development of the Effectiveness Model

The effectiveness model for the wastewater management system (WMS) candidates and the vessels included in this study was developed in accordance with the principles of the effectiveness assessment methodology, following the prescribed step-by-step procedures (see "Results of Applying the Effectiveness Assessment Methodology to the Candidate System Vessel"). Seven measures of effectiveness (M/Es) were chosen as follows:

- Adaptability for shipboard installation
- Performance
- Operability
- Personnel Safety
- Habitability
- Reliability
- Maintainability

Each M/E was then broken down into its constituent factors and subfactors. Weights were then assigned to the M/Es and to the factors and subfactors at each level of subordination.

*It is noted that for purposes of the computer program, the effectiveness model does not include the ERFs and the input data include the elementary factor/subfactor ratings for each candidate system/vessel combination.

An effectiveness rating function (ERF) was then developed for each elementary factor/subfactor. Figure 2 shows the form used for documenting these ERFs. This form also facilitates recording the effectiveness attribute data and effectiveness ratings for each viable candidate system/vessel combination associated with the given ERF. The effectiveness model used resulted in 111 individual ERFs which are uniquely identified by the numbering scheme for factors and subfactors. Thus, each viable candidate system/vessel combination is evaluated on the basis of 111 individual criteria.

Decision-Maker Participation

One of the tenets of this effectiveness assessment methodology is that in order to produce meaningful results, it is necessary for the decision-maker to participate in the development of the effectiveness model. In conformity with this principle, the effectiveness model was developed in consultation with, and the active participation of, cognizant U.S. Coast Guard technical representatives. Such Coast Guard participation was extensive in the development of the structure of the effectiveness model, i.e., the choice of the M/Es and the breakdown of each M/E into its factors/subfactors and the associated levels of subordination. The M/E as well as the factor/subfactor weights assignments were made by the Coast Guard. Finally, the development of the ERFs was carefully coordinated with the Coast Guard technical monitor.

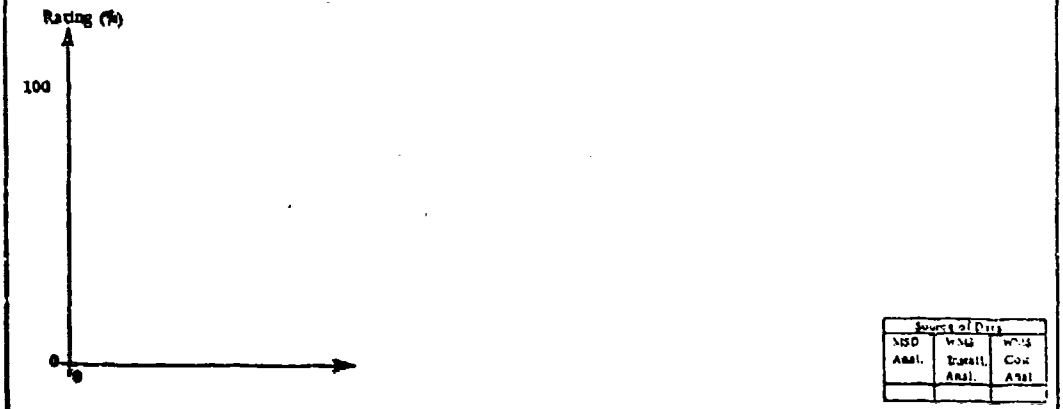
Development and Documentation of Effectiveness Attribute Data

The effectiveness Attribute Data required as input to the effectiveness model is defined by the ERFs. These data came from three different sources which represent three types of analyses performed as part of this study, namely:

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E _____

Effectiveness Rating Function



Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1												
2											N	A
3			N	A							N	A
4			N	A							N	A
5	N	A	N	A							N	A
6	N	A	N	A							N	A
7			N	A							N	A
8	N	A	N	A							N	A
9												
10											N	A
11			N	A								
12	N	A	N	A							N	A
13	N	A	N	A							N	A
14												
15											N	A
16												
17	N	A	N	A							N	A
18	N	A	N	A							N	A

Attribute Data — Rating

N/A - Not a viable system/vessel combination

Figure 2
FORM USED FOR DOCUMENTING EFFECTIVENESS RATING FUNCTIONS AND ASSOCIATED ATTRIBUTE DATA AND RATINGS

- The MSD analysis
- The WMS installation analysis
- The WMS life-cycle cost analysis

Results of the MSD analysis are presented in Volume V of this report. Figure 3 shows a sample form which was used to document MSD related effectiveness attribute data. It is noted from Figure 3 that the MSD effectiveness attribute data was developed and presented on a subsystem level in accordance with the manner in which the MSDs were hybridized to form the candidate WMS concepts. For ease of reference, each MSD subsystem characteristic is keyed to the associated ERF by the unique factor/subfactor identification scheme.

Results of the WMS installation analysis are presented in Volume III of this report. Figure 4 shows a sample form which was used to document WMS installation related effectiveness attribute data. These data were developed and are presented on an overall WMS basis. It is noted from Figure 4 that each WMS installation characteristic is keyed to the associated ERF by the numbering scheme for uniquely identifying each factor and subfactor.

Results of the WMS life-cycle cost analysis are presented in Volume I of this report. Some of the data resulting from this analysis (e.g., vessel resource usage, labor and parts requirements for operation and maintenance), constitute effectiveness attribute data. Most of these data were developed and presented on an overall WMS basis.

The manner in which the above discussed effectiveness attribute data is used for rating elementary factors/subfactors is documented by the corresponding ERFs. In order to facilitate the quantification of effectiveness, the effectiveness attribute data for each viable candidate system/vessel combination was recorded on the form in Figure 2 in the format specified by the ERF. As noted from Figure 2, this form has a provision for indicating the source of the data and it also lists the non-viable system/vessel combinations for which no effectiveness attribute data (and no ratings) were developed.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E II - PERFORMANCE

MSD _____ Sheet 1 of 4

M/E Factor/ Subfactor Ident. No.	PERFORMANCE Characteristics	Attribute Data: Collect./Transp. Subsystem	Attribute Data: Treat./Disposal Subsystem
311	Effect of peak hydraulic loads in black[1] water stream on MSD performance[2] (a) No significant effect of black water peaks on MSD subsystem performance. (b) Effect of black water peaks is of short duration, with temporary implications for MSD subsystem performance, easy to overcome. (c) Long-term effect of black water peaks, difficult to overcome, with long-term implications for MSD subsystem performance. (d) No ability of MSD subsystem to handle black water peaks.		
312	Effect of peak hydraulic loads in gray[1] water stream on MSD performance (2) (a) No significant effect of grey water peaks on MSD subsystem performance. (b) Effect of gray water peaks is of short duration, with temporary implications for MSD subsystem performance, easy to overcome. (c) Long-term effect of gray water peaks, difficult to overcome with long-term implications for MSD subsystem performance. (d) No ability of MSD subsystem to handle gray water peaks.		
321	Effect of low flow conditions/long idle times in black water stream on MSD performance[3] (a) No significant effect of black water low flow conditions/long idle times on MSD subsystem performance. (b) Effect of black water low flow conditions/long idle times of short duration, with temporary implications for MSD subsystem performance, easy to overcome. (c) Long-term effect of black water low flow conditions/long idle times, difficult to overcome, with long-term implications for MSD subsystem performance. (d) No ability of MSD subsystem to handle black water low flow conditions/ long idle times.		

(1) Includes instantaneous, hourly and daily loads.
(2) Peak load handling ability depends on C/T subsystem. The ability of an MSD which employs an influent surge tank to handle peaks usually depends almost entirely on the sizing of this tank.
(3) An example of low flow condition is when 75% of the crew is not on board vessel for a week and usage rate by remaining 25% of crew is normal. Long idle times are on the order of several weeks of virtually no usage of MSD.

Figure 3

SAMPLE DATA FORM USED FOR DOCUMENTING
MSD EFFECTIVENESS ATTRIBUTE DATA

WMS INSTALLATION EFFECTIVENESS ATTRIBUTE DATA

Vessel _____ Sheet 1 of 10

Factor/Subfactor Ident. No.	M/E I - ADAPTABILITY FOR SHIPBOARD INSTALLATION INSTALLATION CHARACTERISTIC																	
111	Required black water handling capacity for vessel versus actual capacity of WMS (a) Actual capacity of WMS equals or exceeds required capacity for vessel. (b) WMS marginally suitable for vessel (has 95-99% of required capacity). (c) WMS capacity insufficient for vessel (less than 95% of required capacity).																	
WMS #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Data																		
112	Required gray water handling capacity for vessel versus actual capacity of WMS (a) Actual capacity of WMS equals or exceeds required capacity for vessel. (b) WMS marginally suitable for vessel (has 95-99% of required capacity). (c) WMS capacity insufficient for vessel (less than 95% of required capacity).																	
WMS #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Data																		
13	Extent of additional support systems or equipment required to accommodate WMS(1) (a) No additional support systems or equipments required. (b) Some additional support systems or equipment required.(2) (c) Many additional support systems or equipments required.(3) (1) Examples: . Firefighting system must be installed with incinerator. . Bilge alarm required if large tank is installed above bilge. . Compressor required on vessels that do not already have one. . Detectors of toxic or noxious gases should be installed with any system that, as an inherent design feature, uses such gases in processing wastes. (2) Need for support system/equipment does not significantly reduce WMS suitability for on-board installation. (3) Suitability of WMS for installation on vessel significantly reduced.																	
WMS #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Data																		
21	Extent of fixture modifications required for WMS installation (a) No fixtures need modification or replacement. (b) Some fixtures need modification or replacement. (c) All commodes need replacement and modification of urinal-associated equipment (e.g., urinal discharge valves) is required. (d) All fixtures need replacement or modification (e.g., replacement of commodes and urinal flushometers). (e) All fixtures need replacement or modification and each fixture has additional hookup requirements associated with it.																	
WMS #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Data																		

Figure 4
SAMPLE FORM USED FOR DOCUMENTING WMS
INSTALLATION EFFECTIVENESS ATTRIBUTE DATA

Some ERFs call for effectiveness attribute data from more than one source, e.g., some elementary factor/subfactor ratings for the M/Es PERSONNEL SAFETY and for HABITABILITY depend on data from both MSD related as well as WMS installation related effectiveness attribute data. In such cases, both sources of data would be indicated on the form in Figure 2. As was noted earlier, MSD related effectiveness attribute data where developed and documented on a subsystem level. Usually, such MSD data are recorded on the form in Figure 2 for the three major subsystems of each WMS concept, namely:

- The black water Collection/Transport subsystem
- The black water Treatment/Disposal subsystem
- The gray water Treatment/Disposal subsystem

The relationship between the above WMS subsystems and corresponding MSD subsystems is conveyed by Tables 1 and 2. These tables serve as a guide to the MSD effectiveness attribute data presented in Volume V of this report. Table 1 enables easy identification of the MSD subsystems corresponding to each WMS concept. Table 2 facilitates easy identification of each WMS concept which utilizes a given MSD subsystem. Thus, if the data for any given MSD subsystem were changed, Table 2 facilitates easy identification of all WMS concepts that would be affected by such a change.

Quantification of Effectiveness

As a first step in the quantification of effectiveness, a rating was obtained for each viable candidate system/vessel combination with respect to each elementary factor/subfactor. This was accomplished by performing the necessary manipulations of the effectiveness attribute data as specified by the attribute variable of each ERF and then using the quantified attribute variable in the functional relationship specified by the ERF. The resulting ratings were recorded on the form shown in Figure 2. These ratings for the elementary factors/subfactors were then used (together with the effectiveness model) to prepare the necessary inputs for the computer program for quantifying effectiveness. The output from the computer program are overall effectiveness ratings as well as ratings with respect to each M/E for each viable system/vessel combination.

Table 1

WMS/MSD CROSS REFERENCE FOR EFFECTIVENESS ATTRIBUTE DATA

WMS No.	Collection/Transport Subsystem (Black)	Treatment/Disposal Subsystem	
		Black	Gray
1	CHT	CHT	CHT
2	Chrysler	Chrysler with Holding Tank	CHT
3	Chrysler	Chrysler with Incinerator	CHT
4	Grumman	Grumman with Holding Tank	CHT
5	Grumman	Grumman with Holding Tank	
6	CHT	CHT	Grumman with Holding Tank
7	Grumman	Grumman with Incinerator	CHT
8	Grumman	Grumman with Incinerator	
9	Jered (1)	CHT	CHT
10	Jered (1)	Jered/Thiokol Incinerator (2)	CHT
11	Jered (1)	GATX	CHT
12	Jered (1)	CHT	Grumman with Holding Tank
13	Jered (1)	Thiokol Incinerator (3)	Grumman with Incinerator
14	GATX	CHT	CHT
15	GATX	Jered/Thiokol Incinerator (3)	CHT
16	GATX	GATX	CHT
17	GATX	CHT	Grumman with Holding Tank
18	GATX	Thiokol Incinerator (3)	Grumman with Incinerator

(1) Large or small boat system, depending on vessel. Effectiveness attribute data based on large boat system.

(2) Jered or Thiokol incinerator, depending on vessel. Effectiveness attribute data based on Jered incinerator.

(3) Thiokol incinerator used in conjunction with the Grumman MSD treating the gray water stream. Effectiveness attribute data based on Jered incinerator.

Table 2

MSD/WMS CROSS REFERENCE FOR EFFECTIVENESS ATTRIBUTE DATA

JERED	
Collection/Transport Subsystem (Black)	Treatment/Disposal Subsystem (Black)
9, 10, 11, 12, 13	10*, 13**, 15*, 18**

GATX	
Collection/Transport Subsystem (Black)	Treatment/Disposal Subsystem (Black)
14, 15, 16, 17, 18	11, 16

CHRYSLER		
Collection/Transport Subsystem (Black)	Treatment/Disposal Subsystem (Black)	
	With Holding Tank	With Incinerator
2, 3	2	3

GRUMMAN				
Collection/Transport Subsystem (Black)	Treatment/Disposal Subsystem			
	With Holding Tank		With Incinerator	
	Black	Gray	Black	Gray
4, 5, 7, 8	4, 5	5, 6, 12, 17	7, 8	8, 13, 18

CHT		
Collection/Transport Subsystem (Black)	Treatment/Disposal Subsystem	
	Black	Gray
1, 6	1, 6, 9, 12, 14, 17	1, 2, 3, 4, 7, 9, 10, 11, 14, 15, 16

* Jered or Thiokol incinerator. Effectiveness attribute date based on Jered incinerator.

** Thiokol incinerator. Effectiveness attribute data based on Jered incinerator.

DEFINITIONS

The definitions of certain terms used in conjunction with this effectiveness assessment methodology are given below.

Attribute

A quantitative or qualitative characteristic of the candidate systems/subsystems/equipments and/or vessels which is used as the basis for assigning an effectiveness rating to elementary factors/subfactors. Attribute is also used in connection with the following:

- Attribute Data

  The quantitative or qualitative "values" of specific attributes or attribute variables for the candidate system/vessel combinations.

- Attribute Variable

  A variable which is used for quantifying an attribute of candidate system/vessel combinations. Attribute variables are often functions which relate attribute data at the system/subsystem/equipment/vessel level to a numerical or qualitative "value" which is used in conjunction with effectiveness rating functions to obtain an effectiveness rating for elementary factors/subfactors.

Effectiveness

The overall quality of a candidate determined on the basis of how well the candidate fulfills specified objectives, requirements and constraints. Effectiveness can be quantified and the resulting number is the effectiveness rating of the candidate which is a quantitative measure of the degree to which the candidate has satisfied the aggregate of all established individual criteria and their relative importance.

Elementary Factor/Subfactor

A factor or subfactor which has no subordinate subfactors and which can be readily related to a single attribute (or a function of one or more attributes) of the candidate system/vessel combinations being analyzed.

Factors

The set of criteria which are implied by a M/E. Factors are characterized (for any candidat system/vessel combination) numerically by two quantities, namely, a rating (which measures how well the candidate satisfies the criterion) and a weight (which indicates how important this factor is in relation to the other factors of the same M/E).

Level of Subordination

The indenture of a given factor or subfactor in the hierarchical structure of the effectiveness model. A numbering scheme used to uniquely identify each factor/subfactor within each M/E indicates the level of subordination.

Measures of Effectiveness (M/Es)

The set of highest level criteria used as the basis for assessing the overall effectiveness of candidate system/vessel combinations. M/Es are characterized (for any candidate system/vessel combination) numberically by two quantities, namely, a rating (which measures how well the candidate satisfies the criterion) and a weight (which indicates how important this M/E is in relation to the others).

Rating

A quantity which measures the degree to which a candidate satisfies either a single criterion or the aggregate of a set of criteria and their relative importance. A rating is given as a percentage in the range of 0 to 100%, using the convention that the higher the rating the greater the degree of acceptability

or quality of the candidate and vice versa. Ratings are used in conjunction with the following:

- Overall effectiveness
- M/Es
- Factors
- Subfactors
- Elementary factors/subfactors

Subfactors

The set of criteria which are implied by a factor or another higher level subfactor. Subfactors are characterized (for any given candidate system/vessel combination) numerically by two quantities, namely a rating (which measures how well the candidate satisfies the criterion) and a weight (which indicates how important this subfactor is in relation to the other subfactors at the same level of subordination under the corresponding factor/subfactor).

Weight

A quantity which indicates the importance of each criterion in relation to the others, at the same level of subordination in the hierarchical structure of the effectiveness model. A weight is given as a percentage in the range of 0 to 100%, using the convention that the higher the weight the more important the criterion (in relation to the others at the same level) and vice versa. Weights are assigned such that their sum is equal to 100 for all criteria at the same (and every) level of subordination. Weights are used in conjunction with the following:

- M/Es
- Factors
- Subfactors
- Elementary factors/subfactors

RESULTS OF APPLYING THE EFFECTIVENESS ASSESSMENT METHODOLOGY TO THE CANDIDATE SYSTEM/VESSEL COMBINATIONS

This section of the report contains the results of applying the effectiveness assessment methodology to the viable candidate system vessel combinations included in this study. The candidate systems are intended for managing both the black (output of commodes, urinals and garbage grinder) and the gray (galley and turbid, i.e., output of sinks, showers, laundry, deck drains, etc.) wastewaters aboard the candidate vessels. The candidate systems consist of the 18 wastewater management system (WMS) concepts in configurations suitable for the vessels included in this study (see Volume IV). Of these potential candidate system/vessel combinations only those considered to be viable candidates on the basis of the installation analysis (see Volume III) were included in the effectivness analysis.

The results of this analysis include the following:

- The structure of the effectiveness model which consists of the measures of effectiveness (M/Es) and the factor/subfactors of each M/E together with their associated levels of subordination.

- Weights for the M/Es and for the factors/subfactors of each M/E at every level of subordination.

- Elementary factor/subfactor ratings for every viable candidate system/vessel combination. These ratings include the following information:

- .. An effectiveness rating function (ERF) for each elementary factor/subfactor identified by the unique numbering system.

- .. Effectiveness attribute data for each viable candidate system/vessel combination in a format specified by the the ERF.

- .. Elementary factor/subfactor ratings for each viable candidate system/vessel combination.

- Overall effectiveness ratings as well as ratings with respect to each M/E for all viable candidate system/vessel combinations.

The results of the effectiveness analysis are given in the order indicated above except for the last item. These ratings appear both in the "Summary of Candidate System/Vessel Effectiveness Assessments" in the front of this report as well as in the discussion of the computer program for quantifying effectiveness as the "Output Report" portion of the sample problem.

STRUCTURE OF THE EFFECTIVENESS MODEL

MEASURES OF EFFECTIVENESS (M/Es)
I - ADAPTABILITY FOR SHIPBOARD INSTALLATION (Suitability for vessel, ease of installing, effects on vessel)
II - PERFORMANCE (How well system accomplishes intended functions)
III - OPERABILITY (Ease of operation, burden on crew, operational expendables)
IV - PERSONNEL SAFETY (Likelihood, severity and ease of correcting hazards)
V - HABITABILITY (Noise, odor, heat, user comfort, aesthetics)
VI - RELIABILITY (Potential for failure free operation)
VII - MAINTAINABILITY (Ease of correcting failures, manpower and logistic requirements)

Factors/Subfactors

of

I - ADAPTABILITY FOR SHIPBOARD INSTALLATION

Ident.		
1	•	WMS suitability for vessel
11	•	Required capacity for vessel vs. actual capacity of system(s)
111	•••	Black
112	•••	Gray
12	••	Materials disallowed or not recommended (as specified in sub-chapter J&F of the Merchant Marine Code and CG MSD regulations)
13	••	Extent of additional support systems/equipment required to accommodate WMS (Compressor, fire fighting equipment, bilge alarm, ozone detector, vents, etc.)
2		Ease of WMS installation
21	••	Extent of fixture modifications (i.e., existing commodes/urinals/fixtures vs. special commodes/urinals/fixtures, including hook-up requirements)
22	••	Extent of flush medium supply modifications (existing sea water or fresh water, conversion to fresh or sea water, conversion to non-aqueous medium)
23	••	Ease of installing wastewater Collection/Transport subsystem (Note VCT for JERED and M/T pumps for GATX)
231	•••	Hook-up requirements (e.g., drain piping, electric cables connecting commode, pump and control panel in GATX, but not in JERED)
232	•••	Routing flexibility for drain piping modifications (e.g., continuous slope and vent requirements for conventional full flush drains vs. JERED and GATX drains)
233	•••	Space requirements
234	•••	Modularity of systems (i.e., single package unit vs. decentralization of components)
235	•••	Vent requirements
24	••	Ease of installing waste Treatment/Disposal subsystem
241	•••	Space requirements
242	•••	Hook-up requirements (piping for fuel oil, fresh water, cooling water, compressed air, interconnecting remotely located equipment, overboard discharge line, etc.; electric cables for power supply, remote control panels, etc.; ducting for ventilation, etc.)

243 ●●● Modularity of system (single package unit vs. decentralization of components; note that decentralization of components may require additional hook-ups and piping runs).

244 ●●● Vent requirements

245 ●●● Exhaust stack requirements

25 ●● Ease of installing WMS support equipment (e.g., compressor, fire fighting, bilge alarm, ozone detector, vents)

26 ●● Ease of compensating for added weight of WMS

27 ●● Degree of vessel alterations required for WMS installation

271 ●●● SHIPALTS - permanent modifications (e.g., foundations, enlarged doors/hatches, increased capacity requirements for air compressor)

272 ●●● Temporary modifications (e.g., cutting access openings)

3 ● Effects of WMS on vessel

31 ●● Stability

32 ●● Trim and list

33 ●● Normal range

34 ●● Degree of space trade-off/reallocation required

35 ●● Vessel resource consumption

351 ●●● Electric power

352 ●●● Fuel oil

353 ●●● Potable water

354 ●●● Compressed air

355 ●●● Cooling water

Factors/Subfactors

of

II - PERFORMANCE

Ident.	
1	• WMS figures of merit
11	•• Per capita energy consumption (electric power; power for ventilation, compressed air, pumping flush medium and cooling water; fuel; fuel for fresh water generated aboard vessel).
12	•• Per capita system weight (wet)
13	•• Per capita system volume
2	• Adequacy of WMS holding times
21	•• Black
22	•• Gray
3	• Ability of WMS to handle, and effects on performance, of abnormal hydraulic loads
31	•• Effect of peak loads
311	••• Black
312	••• Gray
32	•• Effect of low flow conditions and/or long idle items
321	••• Black
322	••• Gray
33	•• Ability to handle additional personnel
331	••• Black
332	••• Gray
4	• WMS designed to operate for sustained time periods (e.g., CHT has limited holding capacity vs. JERED, with incinerator, has indefinite capacity)
41	•• Black
42	•• Gray
5	• Ability of WMS to handle ground garbage and extraneous materials in black water stream
51	•• Ground garbage
52	•• Foreign materials/objects
53	•• Detergents/surfactants
54	•• Toxic materials (as it affects performance of biological system)
6	• Ability of WMS secondary emissions to meet applicable standards
61	•• Discharge of significant air pollutants
62	•• Disposal of oil contaminated residues at sea
7	• Performance risk for WMS configuration (i.e., hybrid systems, experience)
71	•• Black
72	•• Gray

Factors/Subfactors

of

III - OPERABILITY

Ident		
1	•	Ease of WMS operation
11	••	Automatic/semi-automatic/manual operation
12	••	Disposal of residue(s)
13	••	Mode changeovers (primary to overboard discharge cycle/pierside to primary cycle)
14	••	Likelihood of violating effluent standards because of procedural errors (discharge of effluent which doesn't meet emission standards, flush oil, evaporator residue, wastewater or sludge from holding tank, stack emissions from incinerator which do not meet standards, etc.)
2	•	Burden of WMS on crew's operating personnel
21	••	Frequency of operator involvement
22	••	Man-hour requirements
23	••	Skill level requirements
24	••	Training requirements
25	••	Effect on work routines/schedules
26	••	Additional personnel (billets) required
3	•	Operational supplies and support equipment operating requirements for WMS
31	••	Amount of consumables/expendables
32	••	Availability of required specialized or unique consumables/expendables (i.e., vessel inventory, general commercial availability, federal stock system)
33	••	Operating requirements for special or unique WMS support equipment

Factors/Subfactors

of

IV - PERSONNEL SAFETY

Ident.		
1	•	Contact with/spillage of toxic/dangerous substance associated with WMS
11	••	Inherent design feature
12	••	Procedural errors/equipment failures (note repair induced hazards)
2	•	Explosive potential for operator/maintainer of WMS (e.g., pressurized vessels, vapors)
21	••	Inherent design feature
22	••	Procedural errors/equipment failures
3	•	Fire ignition potential of WMS
31	••	Inherent design feature
32	••	Procedural errors/equipment failures
4	•	Electric shock potential to operator/maintainer of WMS
5	•	Physical hazards associated with WMS
51	••	Sharp edges
52	••	Hot surfaces
53	••	Rotating machinery for maintainer

Factors/Subfactors

of

V - HABITABILITY

Ident.		
1	•	Bacterial contamination associated with WMS (user psychological reaction)
11	••	Inherent design feature
12	••	Procedural errors/equipment failures
2	•	Fixture efficacy of WMS
21	••	Comfort
22	••	Flushing procedure requirements
23	••	Waste retention in bowl
24	••	Likelihood of user contact with flushing medium
25	••	Flushing medium appearance
26	••	Flushing noise
3	•	Odors produced by WMS
31	••	Inherent design feature
32	••	Procedural errors/equipment failures
4	•	WMS heat generation for operator/maintainer/adjacent berthing and working areas
41	••	Inherent design feature
42	••	Procedural errors/equipment failures
5	•	Noise levels in vicinity of WMS for operator/maintainer/adjacent berthing and working areas
6	•	Vibration produced by WMS for operator/maintainer/adjacent berthing and working areas
7	•	Effect of WMS on user housekeeping routines

Factors/Subfactors

of

VI - RELIABILITY

Ident.		
1	•	Failure frequency index for WMS
2	•	Reliability index for WMS (system design/configuration)
21	••	System complexity
22	••	Extent of configuration redundancy (e.g., additional head spaces/fixtures throughout vessel)
23	••	Extent of equipment/component redundancy
24	••	Degree of equipment failure independence (i.e., failure of one item will not cause another item to fail)
25	••	Adequacy of equipment ratings
26	••	Provisions for fault actuated cut-off mechanisms to protect system (i.e., provision for fail safe operation)
3	•	Reliability risk for WMS (e.g., hybrid configuration, innovative design, experience)

Factors/Subfactors

of

VII - MAINTAINABILITY

Ident.		
1	•	Corrective Maintenance (CM) requirements for WMS
11	••	Frequency of CM actions (failure frequency)
12	••	Man-hour and skill level requirements
13	••	Ease of repair/replace
131	•••	Accessibility of replaceable components
132	•••	Extent of system modularization
133	•••	Degree of repairability on board vessel (repair vs. replace)
134	•••	Availability of manufacturer field support and training programs
14	••	Spares stockage requirements
141	•••	Extent of spares stockage requirements
142	•••	Special/proprietary items vs. standard supply parts
2	•	Preventive Maintenance (PM) requirements for WMS
21	••	Frequency of PM actions
22	••	Man-hour requirements
23	••	Effect on watchstander routines
3	•	Overhaul Maintenance requirements for WMS
31	••	Frequency of overhauls
32	••	Man-hour and skill level requirements
33	••	Special docking requirements
4	•	Logistic requirements for WMS

WEIGHT ASSIGNMENTS

M/E Weights

MEASURE OF EFFECTIVENESS (M/E)	WEIGHT (%)
I - ADAPTABILITY FOR SHIPBOARD INSTALLATION (Suitability for vessel, ease of installing, effects on vessel)	8
II - PERFORMANCE (How well system accomplishes intended functions)	15
III - OPERABILITY (Ease of operation, burden on crew, operational expendables)	12
IV - PERSONNEL SAFETY (Likelihood, severity and ease of correcting hazards)	11
V - HABITABILITY (Noise, odor, heat, user comfort, aesthetics)	17
VI - RELIABILITY (Potential for failure free operation)	23
VII - MAINTAINABILITY (Ease of correcting failures, manpower and logistic requirements)	14

Factor/Subfactor Weights

for

I - ADAPTABILITY FOR SHIPBOARD INSTALLATION

FACTOR/ SUBFACT. IDENT. NO.	M/E FACTORS AND SUBFACTORS (Description and Level of Subordination)	FACTOR/SUBFACTOR WEIGHTS (%) (As a Function of Vessel) GALLATIN (378')	VIGOROUS (210')	FIREBUSH (180')	PAMLICO (160') (New Constr.)	WHITE SAGE (132')	POINT HERRON (82')
1	. WMS suitability for vessel	20					
11	.. Required capacity for vessel vs. actual capacity of system(s)	55					
111	... Black	90					
112	... Gray	10					
12	.. Materials disallowed or not recommended (as specified in subchapter I&F of the Merchant Marine Code and CG MSD regulations)	10					
13	.. Extent of additional support systems/equipment required to accommodate WMS (Compressor, fire fighting equipment, bilge alarm, ozone detector, vents, etc.)	35					
2	. Ease of WMS installation	50					
21	.. Extent of fixture modifications (i.e., existing commodes/urinals/fixtures vs. special commodes/urinals/fixtures, including hook-up requirements)	15					
22	.. Extent of flush medium supply modifications (existing sea water or fresh water, conversion to fresh or sea water, conversion to non-aqueous medium)	15					
23	.. Ease of installation wastewater Collection/Transport subsystem (Note VCT for JERED and M/T pumps for GATX).	15					
231	... Hook-up requirements (e.g., drain piping, electric cables connecting commode, pump and control panel in GATX, but not in JERED)	10					
232	... Routing flexibility for drain piping modifications (e.g., continuous slope and vent requirements for conventional full flush drains vs. JERED and GATX drains)	25					
233	... Space requirements	25					

Factor/Subfactor Weights

for

I - ADAPTABILITY FOR SHIPBOARD INSTALLATION

FACTOR/ SUBFACTOR IDENT. NO.	M/E FACTORS AND SUBFACTORS (Description and Level of Subordination)	FACTOR/SUBFACTOR WEIGHTS (%) (As a Function of Vessel) GALLATIN (378')	VIGOROUS (210')	FIREBRUSH (180')	PAMLICO (160') (New Constr.)	WHITE SAGE (133')	POINT HERRON (82')
234	... Modularity of systems (i.e., single package unit vs. decentralization of components)	20	20	15	25		
235	... Vent requirements						
24	.. Ease of installing waste Treatment/Disposal subsystem						
241	... Space requirements						
242	... Hook-up requirements (piping for fuel oil, fresh water cooling cooling water, compressed air, interconnecting remotely located equipment, overboard discharge line, etc.; electric cables for power supply, remote control panels, etc.: ducting for ventilation, etc.)	25					
243	... Modularity of system (single package unit vs. decentralization of components; note that decentralization of components may require additional hook-ups and piping runs).	15	10	25			
244	... Vent requirements						
245	... Exhaust stack requirements						
25	.. Ease of installing WMS support equipment (e.g., compressor, fire fighting, bilge alarm, ozone detector, vents)	10	10	20			
26	.. Ease of compensating for added weight of WMS						
27	.. Degree of vessel alterations required for WMS installation						
271	... SHIPALTS - permanent modifications (e.g., foundations, enlarged doors/hatches, increased capacity requirements for air compressor)	75	25				
272	... Temporary modifications (e.g., cutting access opening)						

Factor/Subfactor Weights

for

I - ADAPTABILITY FOR SHIPBOARD INSTALLATION

FACTOR/ SUBFACT. IDENT. NO.	M/E FACTORS AND SUBFACTORS (Description and Level of Subordination)	FACTOR/SUBFACTOR WEIGHTS (%) (As a Function of Vessel) GALLATIN (378')	VIGOROUS (210')	FIREBUSH (180')	PAMLICO (160' New Constr.)	WHITE SAGE (133')	POINT HERON (82')
3	. Effects of WMS on vessel	30	→	→	→	→	→
31	.. Stability	10	→	→	→	→	→
32	.. Trim and list	10	→	→	→	→	→
33	.. Normal range	15	→	→	→	→	→
34	.. Degree of space trade/off reallocation required	40	→	→	→	→	→
35	.. Vessel resource consumption	25	→	→	→	→	→
351	... Electric power	25	→	→	→	→	→
352	... Fuel oil	20	→	→	→	→	→
353	... Potable water	35	→	→	→	→	→
354	... Compressed air	10	→	→	→	→	→
355	... Cooling water	10	→	→	→	→	→

Factor/Subfactor Weights

for

II - PERFORMANCE

FACTOR/ SUBFACT. IDENT. NO.	M/E FACTORS AND SUBFACTORS (Description and Level of Subordination)	FACTOR/SUBFACTOR WEIGHTS (%) (As a Function of Vessel) GALLATIN (378')	VIGOROUS (210')	FIREBUSH (180')	PAMLICO (160' New Constr.)	WHITE SAGE (133')	POINT HERRON (82')
1	. WMS figures of merit	15					
11	.. Per capita energy consumption (electric power; power for ventilation, compressed air, pumping flush medium and cooling water; fuel; fuel for fresh water generated aboard vessel)	30					
12	.. Per capita system weight (wet)	25					
13	.. Per capita system volume	45					
2	. Adequacy of WMS holding times	25					
21	.. Black	90					
22	.. Gray	10					
3	. Ability of WMS to handle, and effects on performance, of abnormal hydraulic loads	5					
31	.. Effect of peak loads	50					
311	... Black	90					
312	... Gray	10					
32	.. Effect of low flow conditions and/or long idle items	20					
321	... Black	65					
322	... Gray	35					
33	.. Ability to handle additional personnel	30					
331	... Black	75					
332	... Gray	25					
4	. WMS designed to operate for sustained time periods (e.g., CHT has limited holding capacity vs. JERED, with incinerator, has indefinite capacity)	15					
41	.. Black	90					
42	.. Gray	10					

Factor/Subfactor Weights

for

II - PERFORMANCE

FACTOR/ SUBFACT. IDENT. NO.	M/E FACTORS AND SUBFACTORS (Description and Level of Subordination)	FACTOR/SUBFACTOR WEIGHTS (%) (As a Function of Vessel) GALLATIN (378')	VIGOROUS (210')	FIREBUSH (180')	PAMLICO (160', New Constr.)	WHITE SAGE (133')	POINT HERRON (82')
5	. Ability of WMS to handle ground garbage and extraneous materials in black water stream	15	→	→	→	→	→
51	.. Ground garbage	65	→	→	→	→	→
52	.. Foreign materials/objects	15	→	→	→	→	→
53	.. Detergents/surfactants	10	→	→	→	→	→
54	.. Toxic materials (as it affects performance of biological system)	10	→	→	→	→	→
6	. Ability of WMS secondary emissions to meet applicable standards	15	→	→	→	→	→
61	.. Discharge of significant air pollutants	40	→	→	→	→	→
62	.. Disposal of oil contaminated residues at sea	60	→	→	→	→	→
7	. Performance risk for WMS configuration (i.e., hybrid systems, experience)	10	→	→	→	→	→
71	.. Black	75	→	→	→	→	→
72	.. Gray	25	→	→	→	→	→

Factor/Subfactor Weights

for

III - OPERABILITY

Sheet 1 of 1

FACTOR/ SUBFACT. IDENT. NO.	M/E FACTORS AND SUBFACTORS (Description and Level of Subordination)	FACTOR/SUBFACTOR WEIGHTS (%) (As a Function of Vessel) GALLATIN (378')	VIGOROUS (210')	FIREBUSH (180')	PAMLICO (160') (New Constr.)	WHITE SAGE (133')	POINT HERRON (82')
1	. Ease of WMS operation	20					
11	.. Automatic/semi-automatic/manual operation	35					
12	.. Disposal of residue(s)	30					
13	.. Mode changeovers (primary to overboard discharge cycle/pierside to primary cycle)	20					
14	.. Likelihood of violating effluent standards because of procedural errors (discharge of effluent which doesn't meet emission standards, flush oil, evaporator residue, wastewater or sludge from holding tank, stack emissions from incinerator which do not meet standards, etc.)	15					
2	. Burden of WMS on crew's operating personnel	50					
21	.. Frequency of operator involvement	30					
22	.. Man-hour requirements	20					
23	.. Skill level requirements	5					
24	.. Training requirements	5					
25	.. Effect on work routines/schedules	10					
26	.. Additional personnel (billets) required	30					
3	. Operational supplies and support equipment operating requirements for WMS	30					
31	.. Amount of consumables/expendables	50					
32	.. Availability of required specialized or unique consumables/ expendables (i.e., vessel inventory, general commercial availability, federal stock system)	30					
33	.. Operating requirements for special or unique WMS support equipment	20					

Factor/Subfactor Weights
for
IV - PERSONNEL SAFETY

FACTOR/ SUBFACT. IDENT. NO.	M/E FACTORS AND SUBFACTORS (Description and Level of Subordination)	FACTOR/SUBFACTOR WEIGHTS (%) (As a Function of Vessel) GALLATIN (378')	VIGOROUS (210')	FIREBUSH (180')	PANDICO (160' New Constr.)	WHITE SAGE (130')	POINT HERRON (82')
1	. Contact with/spillage of toxic/dangerous substance associated with WMS	30					
11	.. Inherent design feature	75					
12	.. Procedural errors/equipment failures (note repair induced hazards)	25					
2	. Explosive potential for operator/maintainer of WMS (e.g., pressurized vessels, vapors)	25					
21	.. Inherent design feature	75					
22	.. Procedural errors/equipment failures	25					
3	. Fire ignition potential of WMS	20					
31	. Inherent design feature	75					
32	.. Procedural errors/equipment failures	25					
4	. Electric shock potential to operator/maintainer of WMS	15					
5	. Physical hazards associated with WMS	10					
51	.. Sharp edges	20					
52	.. Hot surfaces	30					
53	.. Rotating machinery for maintainer	50					

Factor/Subfactor Weights

for

V - HABITABILITY

Sheet 1 of 1

FACTOR/ SUBFACT. IDENT. NO.	M/E FACTORS AND SUBFACTORS (Description and Level of Subordination)	FACTOR/SUBFACTOR WEIGHTS (%) (As a Function of Vessel) GALLATIN (378')	VIGOROUS (210')	FIREBUSH (180')	PAMLICO (160') (New Const.)	WHITE SAGE (133')	POINT HERRON (82')
1	. Bacterial contamination associated with WMS (user psychological reaction)	15					
11	.. Inherent design feature	75					
12	.. Procedural errors/equipment failures	25					
2	. Fixture efficacy of WMS	10					
21	.. Comfort	15					
22	.. Flushing procedure requirements	15					
23	.. Waste retention in bowl	20					
24	.. Likelihood of user contact with flushing medium	25					
25	.. Flushing medium appearance	20					
26	.. Flushing noise	5					
3	. Odors produced by WMS	25					
31	.. Inherent design feature	75					
32	.. Procedural errors/equipment failures	25					
4	. WMS heat generation for operator/maintainer/adjacent berthing working areas	15					
41	.. Inherent design feature	75					
42	.. Procedural errors/equipment failures	25					
5	. Noise levels in vicinity of WMS for operator/maintainer/adjacent berthing and working areas	15					
6	. Vibration produced by WMS for operator/maintainer/adjacent berthing and working areas	15					
7	. Effect of WMS on user housekeeping routines	5					

Factor/Subfactor Weights
for
VI - RELIABILITY

Sheet 1 of 1

FACTOR/ SUBFACT. IDENT. NO.	M/E FACTORS AND SUBFACTORS (Description and Level of Subordination)	FACTOR/SUBFACTOR WEIGHTS (%) (As a Function of Vessel) GALLATIN (378')	VIGOROUS (210')	FIREBUSH (180')	PAMLICO (160') (New Constr.)	WHITE SAGE (133')	POINT HERRON (82')
1	. Failure frequency index for WMS	50					
2	. Reliability index for WMS (system design/configuration)	30					
21	.. System complexity	20					
22	.. Extent of configuration redundancy (e.g., additional head spaces/ fixtures throughout vessel)	25					
23	.. Extent of equipment/component redundancy	25					
24	.. Degree of equipment failure independence (i.e., failure of one item will not cause another item to fail)	15					
25	.. Adequacy of equipment ratings	10					
26	.. Provisions for fault actuated cut-off mechanisms to protect system (i.e., provision for fail safe operation)	5					
3	. Reliability risk for WMS (e.g., hybrid configuration, innovative design, experience)	20					

Factor/Subfactor Weights

for

VII - MAINTAINABILITY

Sheet 1 of 1

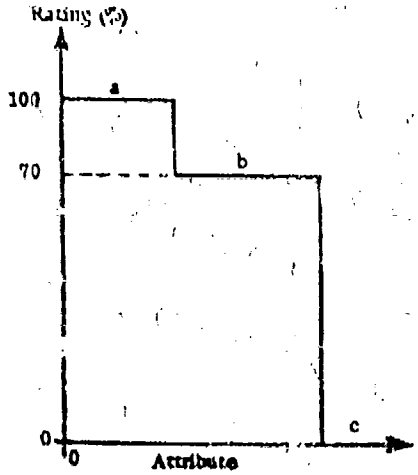
FACTOR/ SUBFACT. IDENT. NO.	M/E FACTORS AND SUBFACTORS (Description and Level of Subordination)	FACTOR/SUBFACTOR WEIGHTS (%) (As a Function of Vessel) GALLATIN (378')	VIGOROUS (210')	FIREBUSH (180')	PAMLICO (160') (New Constr.)	WHITE SAGE (133')	POINT HERRON (82')
1	. Corrective Maintenance (CM) requirements for WMS	40					
11	.. Frequency of CM actions (failure frequency)	35					
12	.. Man-hour and skill level requirements	25					
13	.. Ease of repair/replace	25					
131	... Accessibility of replaceable components	40					
132	... Extent of system modularization	20					
133	... Degree of repairability on board vessel (repair vs. replace)	30					
134	... Availability of manufacturer field support and training programs	10					
14	.. Spares stockage requirements	15					
141	... Extent of spares stockage requirements	60					
142	... Special/proprietary items vs. standard supply parts	40					
2	. Preventive Maintenance (PM) requirements for WMS	25					
21	.. Frequency of PM actions	35					
22	.. Man-hour requirements	45					
23	.. Effect on watchstander routines	20					
3	. Overhaul Maintenance requirements for WMS	20					
31	.. Frequency of overhauls	40					
32	.. Man-hour and skill level requirements	40					
33	.. Special docking requirements	20					
4	. Logistic requirements for WMS	15					

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E I - ADAPABILITY FOR SHIPBOARD INSTALLATION

111	Required black water handling capacity for vessel vs. actual capacity of WMS

Effectiveness Rating Function



(a) Actual capacity of WMS equals or exceeds required capacity for vessel.

(b) WMS marginally suitable for vessel (has 95-99% of required capacity).

(c) WMS capacity insufficient for vessel (less than 95% of required capacity).

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
	✓	

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	a	100	c	0	a	100	a	100	a	100	c	0
2	a	100	c	0	a	100	a	100	a	100	N	A
3	a	100	N	A	a	100	a	100	a	100	N	A
4	a	100	N	A	a	100	a	100	a	100	N	A
5	N	A	N	A	a	100	a	100	a	100	N	A
6	N	A	N	A	a	100	a	100	a	100	N	A
7	a	100	N	A	a	100	a	100	a	100	N	A
8	N	A	N	A	a	100	a	100	a	100	N	A
9	a	100	c	0	a	100	a	100	a	100	a	100
10	a	100	a	100	a	100	a	100	a	100	N	A
11	a	100	N	A	a	100	a	100	a	100	a	100
12	N	A	N	A	a	100	a	100	a	100	N	A
13	N	A	N	A	a	100	a	100	a	100	N	A
14	a	100	a	100	a	100	a	100	a	100	a	100
15	a	100	a	100	a	100	a	100	a	100	N	A
16	a	100	a	100	a	100	a	100	a	100	a	100
17	N	A	N	A	a	100	a	100	a	100	N	A
18	N	A	N	A	a	100	a	100	a	100	N	A

Attribute Data ↑ ↑ Rating

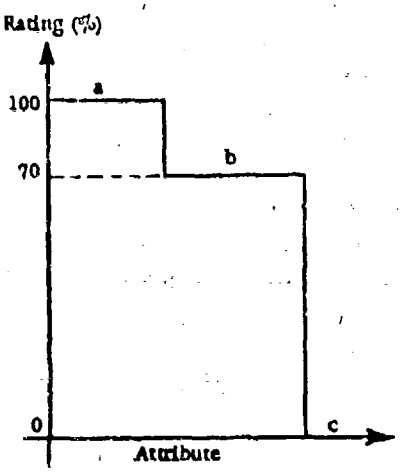
N/A = Not a viable system/vessel combination

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E I - ADAPABILITY FOR SHIPBOARD INSTALLATION

112	Required gray water handling capacity for vessel vs. actual capacity of WMS

Effectiveness Rating Function



(a) Actual capacity of WMS equals or exceeds required capacity for vessel.

(b) WMS marginally suitable for vessel (has 95-99% of required capacity).

(c) WMS capacity insufficient for vessel (less than 95% of required capacity).

Source of Data		
NSD Anal.	WMS Install. Anal.	WMS Cost Anal.
	✓	

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	c	0	c	0	c	0	c	0	a	100	c	0
2	c	0	c	0	c	0	c	0	a	100	N	A
3	c	0	N	A	c	0	c	0	a	100	N	A
4	c	0	N	A	c	0	c	0	a	100	N	A
5	N	A	N	A	a	100	a	100	a	100	N	A
6	N	A	N	A	a	100	a	100	a	100	N	A
7	c	0	N	A	c	0	c	100	a	100	N	A
8	N	A	N	A	a	100	a	100	a	100	N	A
9	c	0	c	0	c	0	c	0	a	100	c	0
10	c	0	c	0	c	0	c	0	a	100	N	A
11	c	0	N	A	c	0	c	0	a	100	c	0
12	N	A	N	A	a	100	a	100	a	100	N	A
13	N	A	N	A	a	100	a	100	a	100	N	A
14	c	0	c	0	c	0	c	0	a	100	c	0
15	c	0	c	0	c	0	c	0	a	100	N	A
16	c	0	c	0	c	0	c	0	a	100	c	0
17	N	A	N	A	a	100	a	100	a	100	N	A
18	N	A	N	A	a	100	a	100	a	100	N	A

Attribute Data ↑ ↑ Rating

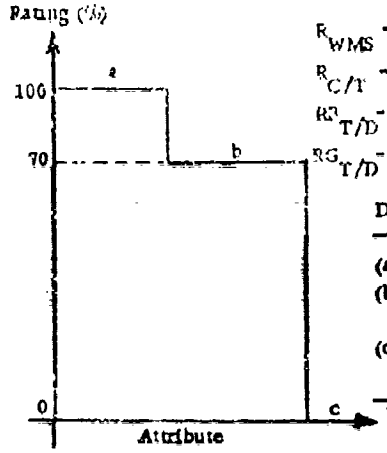
N/A - Not a viable system/vessel combination

M/E I - ADAPABILITY FOR SHIPBOARD INSTALLATION

12 WMS materials disallowed or not recommended*

Effectiveness Rating Function

$R_{WMS} = Min\,(R_{C/T}, RB_{T/D}, RG_{T/D})$



R_{WMS} - Rating for WMS

$R_{C/T}$ - Rating for (black water) C/T subsystem

$RB_{T/D}$ - Rating for black water T/D subsystem

$RG_{T/D}$ - Rating for gray water T/D subsystem

Data given in the form:

$Z_{C/T}, ZB_{T/D}, ZG_{T/D}$ } Attribute

$R_{C/T}, RB_{T/D}, RG_{T/D}$ } Ratings

Definitions of $Z_{C/T}, ZB_{T/D}, ZG_{T/D}$

(a) No disallowed or not recommended materials present in WMS subsystem. **

(b) Some disallowed or not recommended materials present, in WMS subsystem, but resultant problems can be solved or compensated for.

(c) Presence of disallowed or not recommended materials in WMS subsystem presents problems with no feasible solutions.

* As specified in subchapters J&F of Merchant Marine Code and C.G. MSD Regulations.

** For purposes of this study, C.G. directs choice (a) for every WMS.

Source of Data		
MSD Anal.	WMS Initial Anal.	WMS Cost Anal.
✓		

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (160')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1					q, a, g	100						
2											N	A
3			N	A							N	A
4			N	A							N	A
5	N	A	N	A							N	A
6	N	A	N	A							N	A
7			N	A							N	A
8	N	A	N	A							N	A
9												
10											N	A
11			N	A								
12	N	A	N	A							N	A
13	N	A	N	A							N	A
14												
15											N	A
16												
17	N	A	N	A							N	A
18	N	A	N	A							N	A

Attribute Data — Rating

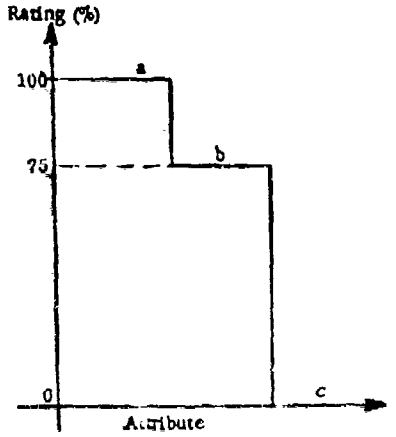
N/A - Not a viable system/vessel combination

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E I - ADAPABILITY FOR SHIPBOARD INSTALLATION

13	Extent of additional support systems or equipment required to accommodate WMS

Effectiveness Rating Function



(a) No additional support systems or equipments required.

(b) Some additional support systems or equipments required. *

(c) Many additional support systems or equipments required. **

Examples:

- Firefighting system must be installed with incinerator.
- Bilge alarm required if large tank is installed above bilge.
- Compressor required on vessels that do not already have one.
- Detectors of toxic or noxious gases should be installed with any system that, as an inherent design feature, uses such gases in processing wastes.

* Need for support system/equipment does not significantly reduce WMS suitability for on-board installation.

** Suitability on WMS for installation on vessel is significantly reduced.

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Con Anal.
✓	✓	

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	b	75	b	75	b	75	b	75	b	75	b	75
2	b	75	b	75	b	75	b	75	b	75	N	A
3	b	75	N	A	b	75	b	75	b	75	N	A
4	b	75	N	A	b	75	b	75	b	75	N	A
5	N	A	N	A	b	75	b	75	b	75	N	A
6	N	A	N	A	b	75	b	75	b	75	N	A
7	b	75	N	A	b	75	b	75	b	75	N	A
8	N	A	N	A	b	75	b	75	b	75	N	A
9	b	75	b	75	b	75	b	75	b	75	b	75
10	b	75	b	75	b	75	b	75	b	75	N	A
11	b	75	b	N	A	b	75	b	75	b	75	b	75
12	N	A	N	A	b	75	b	75	b	75	N	A
13	N	A	N	A	b	75	b	75	b	75	N	A
14	b	75	b	75	b	75	b	75	b	75	b	75
15	b	75	b	75	b	75	b	75	b	75	N	A
16	b	75	b	75	b	75	b	75	b	75	b	75
17	N	A	N	A	b	75	b	75	b	75	N	A
18	N	A	N	A	b	75	b	75	b	75	N	A

Attribute Data ↑ ↑ Rating

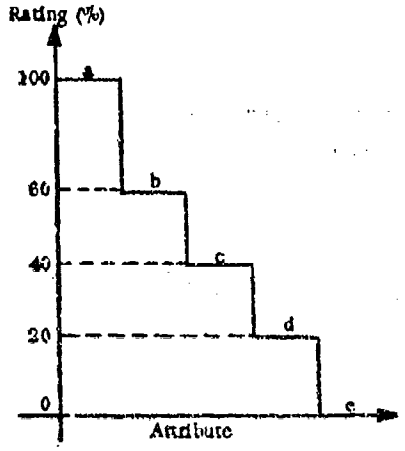
N/A - Not a viable system/vessel combination

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E I - ADAPABILITY FOR SHIPBOARD INSTALLATION

21	Extent of fixture modifications required for WMS installation

Effectiveness Rating Function



(a) No fixtures need modification or replacement.

(b) Some fixtures need modification or replacement.

(c) All commodes need replacement and modification of urinal-associated equipment (e.g., urinal discharge valves) is required.

(d) All fixtures need replacement or modification (e.g., replacement of commodes and urinal flushometers).

(e) All fixtures need replacement or modification and each fixture has additional hookup requirements associated with it.

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
✓	✓	

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	a	100	a	100	a	100	d	20	a	100	a	100
2	a	100	a	100	a	100	d	20	a	100	N	A
3	a	100	N	A	a	100	d	20	a	100	N	A
4	a	100	N	A	a	100	d	20	a	100	N	A
5	N	A	N	A	a	100	d	20	a	100	N	A
6	N	A	N	A	a	100	d	20	a	100	N	A
7	a	100	N	A	a	100	d	20	a	100	N	A
8	N	A	N	A	a	100	d	20	a	100	N	A
9	c	40	c	40	c	40	a	100	c	40	c	40
10	c	40	c	40	c	40	a	100	c	40	N	A
11	c	40	N	A	c	40	a	100	c	40	c	40
12	N	A	N	A	c	40	a	100	c	40	N	A
13	N	A	N	A	c	40	a	100	c	40	N	A
14	e	0	e	0	e	0	e	0	e	0	e	0
15	e	0	e	0	e	0	e	0	e	0	N	A
16	e	0	e	0	e	0	e	0	e	0	e	0
17	N	A	N	A	e	0	e	0	e	0	N	A
18	N	A	N	A	e	0	e	0	e	0	N	A

Attribute Data ↑ ↑ Rating

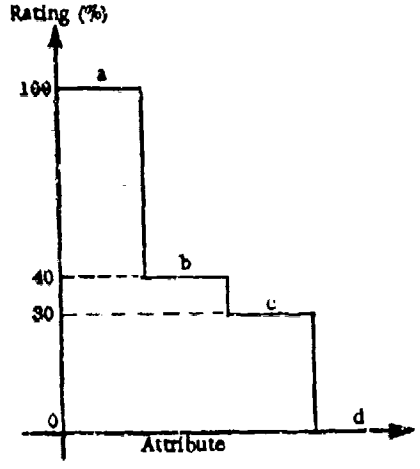
N/A - Not a viable system/vessel combination

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E I - ADAPABILITY FOR SHIPBOARD INSTALLATION

22	Extent of flush meduim supply modifications required for WMS installation

Effectiveness Rating Function



(a) Existing flush medium is used.

(b) WMS requires conversion of flush medium to potable water.

(c) WMS requires conversion of flush medium to recirculating non-aqueous medium.

(d) WMS requires conversion of flush medium to salt water. *

* Convension to salt water requires pump re-sizing, tapping into the sea-chest and provision for its corrosive properties. For the PAMLICO, salt water would be used if the drain system were converted to a standard flush system (C.G. supplied information).

Source of Data		
ESD Anal.	WMS Install. Anal.	WMS Cost Anal.
✓	✓	

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	a	100	a	100	a	100	d	0	a	100	a	100
2	c	30	c	30	c	30	c	30	c	30	N	A
3	c	30	N	A	c	30	c	30	c	30	N	A
4	a	100	N	A	a	100	d	0	a	100	N	A
5	N	A	N	A	a	100	d	0	a	100	N	A
6	N	A	N	A	a	100	d	0	a	100	N	A
7	a	100	N	A	a	100	d	0	a	100	N	A
8	N	A	N	A	a	100	d	0	a	100	N	A
9	b	40	b	40	b	40	a	100	b	40	b	40
10	b	40	b	40	b	40	a	100	b	40	N	A
11	b	40	N	A	b	40	a	100	b	40	b	40
12	N	A	N	A	b	40	a	100	b	40	N	A
13	N	A	N	A	b	40	a	100	b	40	N	A
14	b	40	b	40	b	40	a	100	b	40	b	40
15	b	40	b	40	b	40	a	100	b	40	N	A
16	b	40	b	40	b	40	a	100	b	40	b	40
17	N	A	N	A	b	40	a	100	b	40	N	A
18	N	A	N	A	b	40	a	100	b	40	N	A

Attribute Data ↑ ↑ Rating

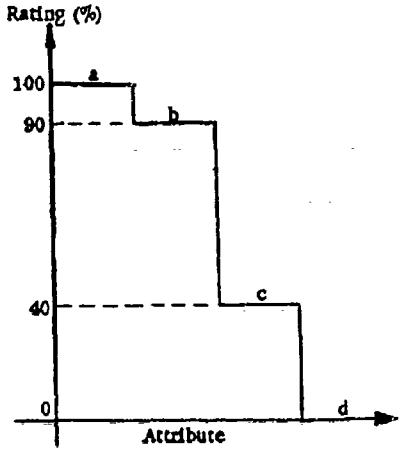
N/A = Not a viable system/vessel combination

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E I - ADAPABILITY FOR SHIPBOARD INSTALLATION

231	Hookup requirements* for WMS Collection/Transport subsystem installation

Effectiveness Rating Function



(a) No additional hookup requirements beyond existing ones.

(b) Requires piping for recirculation of flush medium (in existing gravity drain system).

(c) Special and centralized Collection/Transport subsystem required.

(d) Special and non-centralized Collection/Transport subsystem required (includes conversion from reduced flush vacuum collection to a standard gravity drain system, with or without recirculation).

NOTE: If the WMS is an MSD being installed on a vessel with a standard drain system and no existing WMS, the following ratings would apply to the basic MSDs considered in this study.

100 - CHT, Grumman
90 - Chrysler
40 - JERED
0 - GATX

E.g., drain piping; electric cables connecting commode, M/T pump and control panel in GATX, but not in JERED.

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
✓	✓	

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	a	100	a	100	a	100	d	0	a	100	a	100
2	b	90	b	90	b	90	d	0	b	90	N	A
3	b	90	N	A	b	90	d	0	b	90	N	A
4	a	100	N	A	a	100	d	0	a	100	N	A
5	N	A	N	A	a	100	d	0	a	100	N	A
6	N	A	N	A	a	100	d	0	a	100	N	A
7	a	100	N	A	a	100	d	0	a	100	N	A
8	N	A	N	A	a	100	d	0	a	100	N	A
9	c	40	c	40	c	40	a	100	c	40	c	40
10	c	40	c	40	c	40	a	100	c	40	N	A
11	c	40	N	A	c	40	a	100	c	40	c	40
12	N	A	N	A	c	40	a	100	c	40	N	A
13	N	A	N	A	c	40	a	100	c	40	N	A
14	d	0	d	0	d	0	d	0	d	0	d	0
15	d	0	d	0	d	0	d	0	d	0	N	A
16	d	0	d	0	d	0	d	0	d	0	d	0
17	N	A	N	A	d	0	d	0	d	0	N	A
18	N	A	N	A	d	0	d	0	d	0	N	A

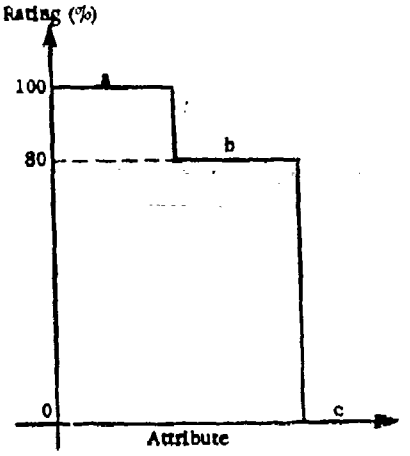
Attribute Data ↑ ↑ Rating

N/A - Not a viable system/vessel combination

M/E I - ADAPABILITY FOR SHIPBOARD INSTALLATION

232 Routing flexibility for drain piping modifications* associated with WMS Collection/Transport subsystem installation**

Effectiveness Rating Function



(a) Routing is highly flexible.

(b) Routing is moderately flexible, with some restrictions.

(c) Routing is highly inflexible.

NOTES: 1. With gravity drainage, lines must always slope downward and require venting.
2. Smaller size lines are inherently more flexible.
3. With the pump or vacuum Collection/Transport subsystem, sharp bends, rises and long runs can be accommodated in piping.

* Of the three relevent categories of routing of lines (piping, ventilation, electrical), piping is the most important for assessing use of WMS installation.

** In all cases, WMS installation is to be considered from the point of view of modifications required to existing conditions.

Source of Data		
NSP Anal.	WMS Install. Anal.	WMS Cost Anal.
✓	✓	

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	a	100	a	100	a	100	b	80	a	100	a	100
2	a	100	a	100	b	80	b	80	a	100	N	A
3	a	100	N	A	b	80	b	80	a	100	N	A
4	a	100	N	A	b	80	b	80	a	100	N	A
5	N	A	N	A	b	80	b	80	a	100	N	A
6	N	A	N	A	b	80	b	80	a	100	N	A
7	a	100	N	A	b	80	b	80	a	100	N	A
8	N	A	N	A	b	80	b	80	a	100	N	A
9	b	80	b	80	b	80	a	100	b	80	b	80
10	b	80	b	80	b	80	a	100	b	80	N	A
11	b	80	N	A	b	80	a	100	b	80	b	80
12	N	A	N	A	b	80	a	100	b	80	N	A
13	N	A	N	A	b	80	a	100	b	80	N	A
14	b	80	b	80	b	80	b	80	b	80	b	80
15	b	80	b	80	b	80	b	80	b	80	N	A
16	b	80	b	80	b	80	b	80	b	80	b	80
17	N	A	N	A	b	80	b	80	b	80	N	A
18	N	A	N	A	b	80	b	80	b	80	N	A

Attribute Data ↑ ↑ Rating

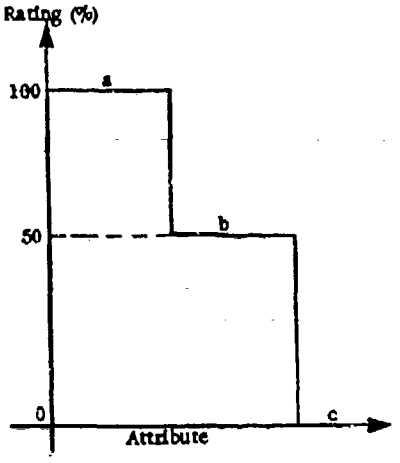
N/A - Not a viable system/vessel combination

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E I - ADAPABILITY FOR SHIPBOARD INSTALLATION

233	Space requirements for WMS Collection/Transport subsystem installation

Effectiveness Rating Function



(a) No additional space required.

(b) Some additional space required.*

(c) Large amount of additional space required.**

* E.g., M/T pumps in GATX; or small influent surge tank.

** E.g., large VCT in JERED; or large influent surge tank, if not already installed.

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
✓	✓	

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	a	100	a	100	a	100	a	100	a	100	a	100
2	b	50	a	100	b	50	b	50	b	50	N	A
3	b	50	N	A	b	50	b	50	b	50	N	A
4	b	50	N	A	a	100	b	50	a	100	N	A
5	N	A	N	A	a	100	b	50	a	100	N	A
6	N	A	N	A	a	100	b	50	a	100	N	A
7	b	50	N	A	a	100	b	50	a	100	N	A
8	N	A	N	A	b	50	b	50	a	100	N	A
9	b	50	b	50	b	50	a	100	a	100	b	50
10	b	50	b	50	b	50	a	100	b	50	N	A
11	b	50	N	A	b	50	a	100	b	50	b	50
12	N	A	N	A	b	50	a	100	b	50	N	A
13	N	A	N	A	b	50	a	100	b	50	N	A
14	a	100	a	100	a	100	a	100	a	100	a	100
15	a	100	a	100	a	100	a	100	a	100	N	A
16	a	100	a	100	a	100	a	100	a	100	a	100
17	N	A	N	A	b	50	a	100	a	100	N	A
18	N	A	N	A	a	100	a	100	a	100	N	A

Attribute Data ↑ ↑ Rating

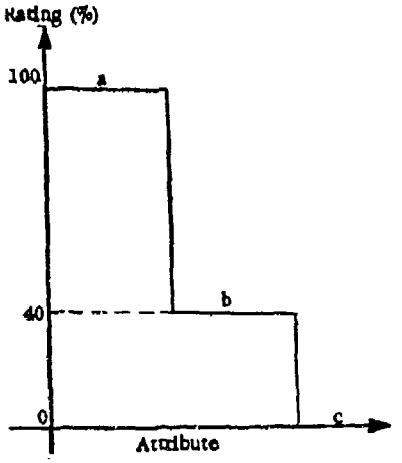
N/A - Not a viable system/vessel combination

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E I - ADAPABILITY FOR SHIPBOARD INSTALLATION

234	Modularity of WMS Collection/Transport subsystem (as it affects installation)

Effectiveness Rating Function



(a) Degree of modularity of subsystem aids in installation of C/T subsystem.

(b) Degree of modularity of subsystem results in some (minimal) difficulty in installation of C/T subsystem.

(c) Degree of modularity of subsystem results in moderate difficulty in installation of C/T subsystem.

NOTE: On vessels that do not currently have a WMS, a high degree of modularity aids in installation, and a high degree of subsystem centralization (as in the JERED) results in difficulties for installation.

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
✓	✓	

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	a	100	a	100	a	100	a	100	a	100	a	100
2	a	100	a	100	a	100	a	100	a	100	N	A
3	a	100	N	A	a	100	a	100	a	100	N	A
4	a	100	N	A	a	100	a	100	a	100	N	A
5	N	A	N	A	a	100	a	100	a	100	N	A
6	N	A	N	A	c	0	a	100	a	100	N	A
7	a	100	N	A	a	100	a	100	a	100	N	A
8	N	A	N	A	a	100	a	100	a	100	N	A
9	a	100	b	40	a	100	a	100	a	100	a	100
10	a	100	b	40	a	100	a	100	a	100	N	A
11	a	100	N	A	a	100	a	100	a	100	a	100
12	N	A	N	A	a	100	a	100	a	100	N	A
13	N	A	N	A	a	100	a	100	a	100	N	A
14	a	100	a	100	a	100	a	100	a	100	a	100
15	a	100	a	100	a	100	a	100	a	100	N	A
16	a	100	a	100	a	100	a	100	a	100	a	100
17	N	A	N	A	a	100	a	100	a	100	N	A
18	N	A	N	A	a	100	a	100	a	100	N	A

Attribute Data ↑ ↑ Rating

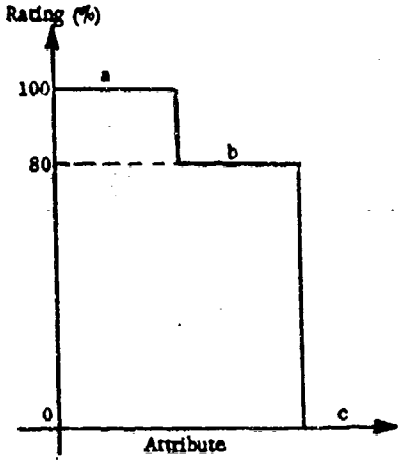
N/A - Not a viable system/vessel combination

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E I - ADAPABILITY FOR SHIPBOARD INSTALLATION

235	Vent requirements for WMS Collection/Transport subsystem installation

Effectiveness Rating Function



(a) No vents are required other than the existing vents.

(b) Few vents are required in addition to the existing vents.

(c) Many vents are required in addition to the existing vents.

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
✓	✓	

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	b	80	a	100	a	100	a	100	a	100	a	100
2	b	80	b	80	b	80	b	80	b	80	N	A
3	b	80	N	A	b	80	b	80	b	80	N	A
4	b	80	N	A	b	80	b	80	a	100	N	A
5	N	A	N	A	b	80	b	80	a	100	N	A
6	N	A	N	A	b	80	b	80	a	100	N	A
7	b	80	N	A	b	80	b	80	b	80	N	A
8	N	A	N	A	b	80	b	80	b	80	N	A
9	b	80	b	80	b	80	a	100	b	80	b	80
10	b	80	b	80	b	80	a	100	b	80	N	A
11	b	80	N	A	b	80	a	100	b	80	b	80
12	N	A	N	A	b	80	b	80	b	80	N	A
13	N	A	N	A	b	80	b	80	b	80	N	A
14	b	80	a	100	a	100	b	80	a	100	b	80
15	b	80	a	100	a	100	b	80	a	100	N	A
16	b	80	b	80	a	100	b	80	a	100	b	80
17	N	A	N	A	a	100	b	80	a	100	N	A
18	N	A	N	A	a	100	b	80	a	100	N	A

Attribute Data ↑ ↑ Rating

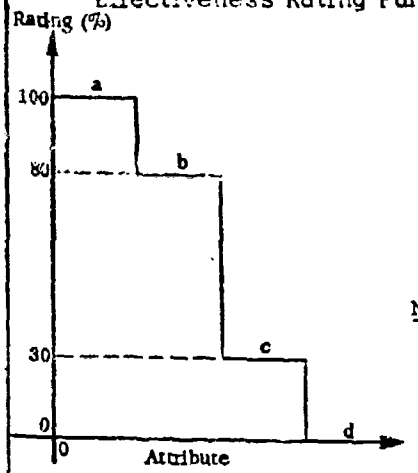
N/A - Not a viable system/vessel combination

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E I - ADAPABILITY FOR SHIPBOARD INSTALLATION

241	Space requirements for WMS waste Treatment/Disposal subsystem installation

Effectiveness Rating Function



(a) Volume required is minimal and dimensions* of equipment present no problems in fitting equipment into available compartment space.

(b) Volume required is moderate and dimensions* of equipment present no problems in fitting equipment into available compartment space.

(c) Volume required is moderate and dimensions* equipment do present a problem in fitting equipment into available compartment space.

(d) Large volume required and dimensions* of equipment do present a problem in fitting equipment into available compartment space.

* The two main factors are (i) deck area required and (ii) height required.

NOTE: Volumes are calculated as follows:

(1) Fixture volumes are calculated using smallest space envelopes.

(2) Pipe volume is the volume of a square tube with side = outside diameter of pipe.

(3) Other equipment: deck area: smallest rectangle enclosing all equipment in a single package plus extra dimension area required for operation and maintenance. Height: either maximum height of equipmen, or full compartment height, if space above is not usable for any other purposes.

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
	✓	

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	b	80	a	100	d	0	b	80	a	100	a	100
2	b	80	b	80	b	80	b	80	b	80	N	A
3	b	80	N	A	b	80	b	80	b	80	N	A
4	b	80	N	A	b	80	b	80	b	80	N	A
5	N	A	N	A	b	80	b	80	a	100	N	A
6	N	A	N	A	b	80	b	80	b	80	N	A
7	b	80	N	A	b	80	b	80	b	80	N	A
8	N	A	N	A	b	80	b	80	b	80	N	A
9	b	80	b	80	b	80	b	80	a	100	c	30
10	b	80	b	80	b	80	b	80	b	80	N	A
11	d	0	N	A	b	80	b	80	b	80	c	30
12	N	A	N	A	b	80	b	30	b	80	N	A
13	N	A	N	A	b	80	b	80	b	80	N	A
14	b	80	a	100	d	0	b	80	b	80	a	100
15	b	80	b	80	b	80	b	80	b	80	N	A
16	c	30	c	30	b	80	b	80	b	80	b	80
17	N	A	N	A	b	80	b	80	b	80	N	A
18	N	A	N	A	b	80	b	80	b	80	N	A

Attribute Data ↑ ↑ Rating

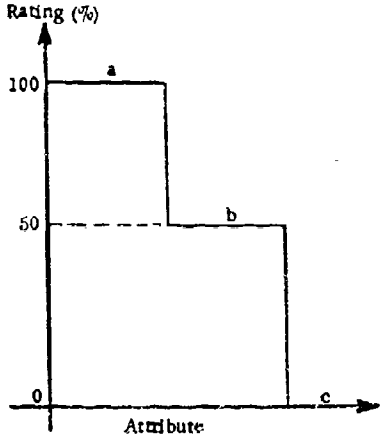
N/A - Not a viable system/vessel combination

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E I - ADAPABILITY FOR SHIPBOARD INSTALLATION

242	Hookup requirements* for WMS waste Treatment/Disposal subsystem installation

Effectiveness Rating Function



(a) Pipes, ducts and/or cable requirements are minimal.

(b) Pipes, ducts and/or cable requirements are moderate.

(c) Pipes, ducts and/or cable requirements are extensive.

* Piping for fuel oil, fresh water, cooling water, compressed air, interconnecting remotely located equipment, overboard discharge line, etc.; electric cables for power supply, remote control panels, etc.; ducting for ventilation, etc.

Source of Data		
NSD Anal.	WMS Install. Anal.	WMS Cost Anal.
✓	✓	

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HEPRON (82')	
1	a	100	a	100	b	50	c	0	a	100	a	100
2	b	50	b	50	b	50	c	0	b	50	N	A
3	b	50	N	A	b	50	c	0	b	50	N	A
4	b	50	N	A	b	50	c	0	b	50	N	A
5	N	A	N	A	b	50	c	0	b	50	N	A
6	N	A	N	A	b	50	c	0	b	50	N	A
7	b	50	N	A	b	50	c	0	b	50	N	A
8	N	A	N	A	b	50	c	0	b	50	N	A
9	b	50	b	50	b	50	b	50	b	50	b	50
10	b	50	b	50	b	50	b	50	b	50	N	A
11	c	0	N	A	b	50	b	50	b	50	b	50
12	N	A	N	A	b	50	b	50	b	50	N	A
13	N	A	N	A	b	50	b	50	b	50	N	A
14	b	50	b	50	b	50	b	50	b	50	b	50
15	b	50	c	0	b	50	b	50	b	50	N	A
16	c	0	c	0	b	50	b	50	b	50	b	50
17	N	A	N	A	b	50	b	50	b	50	N	A
18	N	A	N	A	b	50	b	50	b	50	N	A

Attribute Data ← Rating

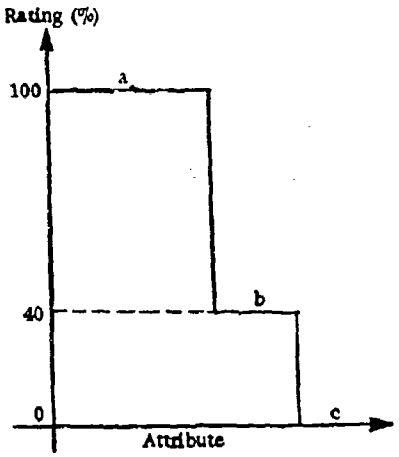
N/A - Not a viable system/vessel combination

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E I - ADAPABILITY FOR SHIPBOARD INSTALLATION

243	Degree of modularity of WMS waste Treatment/Disposal (as it affects installation)

Effectiveness Rating Function



(a) Degree of modularity of subsystem aids in installation of T/D subsystem.

(b) Degree of modularity of subsystem results in some (minimal) difficulty in installation of T/D subsystem.

(c) Degree of modularity of subsystem results in moderate difficulty in installation of T/D subsystem.

NOTE: Decentralization of compartments may require additional hookups and piping runs.

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
✓	✓	

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALIATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	a	100	a	100	a	100	b	40	a	100	a	100
2	a	100	a	100	a	100	a	100	a	100	N	A
3	a	100	N	A	a	100	a	100	a	100	N	A
4	b	40	N	A	a	100	a	100	a	100	N	A
5	N	A	N	A	a	100	a	100	a	100	N	A
6	N	A	N	A	a	100	a	100	a	100	N	A
7	b	40	N	A	a	100	a	100	a	100	N	A
8	N	A	N	A	a	100	a	100	a	100	N	A
9	b	40	a	100	a	100	a	100	a	100	a	100
10	b	40	a	100	a	100	a	100	a	100	N	A
11	b	40	N	A	a	100	a	100	a	100	c	0
12	N	A	N	A	a	100	a	100	a	100	N	A
13	N	A	N	A	a	100	a	100	a	100	N	A
14	a	100	a	100	a	100	a	100	a	100	a	100
15	b	40	b	40	a	100	a	100	a	100	N	A
16	b	40	b	40	a	100	a	100	a	100	c	0
17	N	A	N	A	a	100	a	100	a	100	N	A
18	N	A	N	A	a	100	a	100	a	100	N	A

Attribute Data ↑ ↑ Rating

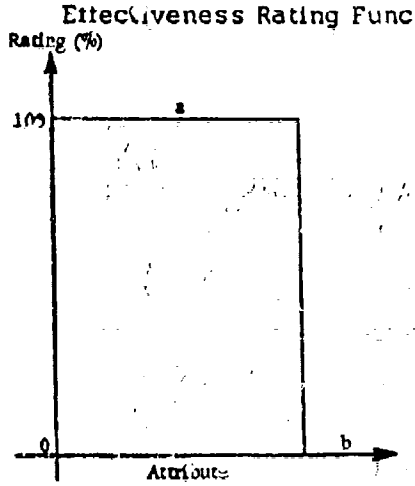
N/A -- Not a viable system/vessel combination

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E I - ADAPABILITY FOR SHIPBOARD INSTALLATION

244	Vent requirements for WMS waste Treatment/Disposal subsystem installation

Effectiveness Rating Function



(a) No vents are required.

(b) Vents are required.

NOTE: Vents that are only internal to the compartment in which subsystem is located are not considered here.

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
✓	✓	

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBRISH (180')		PIMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	a	100	a	100	a	100	b	0	a	100	a	100
2	b	0	b	0	b	0	b	0	b	0	N	A
3	b	0	N	A	b	0	b	0	b	0	N	A
4	b	0	N	A	b	0	b	0	b	0	N	A
5	N	A	N	A	b	0	b	0	b	0	N	A
6	N	A	N	A	b	0	b	0	b	0	N	A
7	b	0	N	A	b	0	b	0	b	0	N	A
8	N	A	N	A	b	0	b	0	b	0	N	A
9	b	0	b	0	b	0	b	0	b	0	b	0
10	b	0	b	0	b	0	b	0	b	0	N	A
11	b	0	N	A	b	0	b	0	b	0	b	0
12	N	A	N	A	b	0	b	0	b	0	N	A
13	N	A	N	A	b	0	b	0	b	0	N	A
14	b	0	b	0	a	100	b	0	b	0	a	100
15	b	0	b	0	b	0	b	0	b	0	N	A
16	b	0	b	0	b	0	b	0	b	0	b	0
17	N	A	N	A	b	0	b	0	b	0	N	A
18	N	A	N	A	b	0	b	0	b	0	N	A

Attribute Data ↑ ↑ Rating

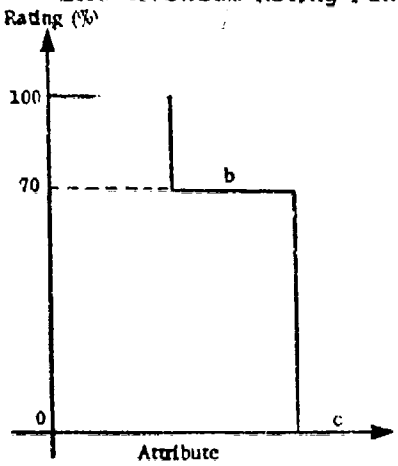
N/A - Not a viable system/vessel combination

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E I - ADAPABILITY FOR SHIPBOARD INSTALLATION

25	Ease of installing WMS support equipment

Effectiveness Rating Function



(a) No support equipn ent required.

(b) Some support equipment required but easy to install

(c) Much support equipment required and difficult to install

Examples:

- Firefighting system must be installed with incinerator.
- Bilge alarm required if large tank is installed above bilge.
- Compressor required on vessels that do not already have one.
- Detectors of toxic or noxious gases should be installed with any system that, as an inherent design feature, uses such gases in processing wastes.

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal
✓	✓	

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	b	70	b	70	b	70	b	70	b	70	b	70
2	b	70	b	70	b	70	b	70	b	70	N	A
3	b	70	N	A	b	70	b	70	b	70	N	A
4	b	70	N	A	b	70	b	70	b	70	N	A
5	N	A	N	A	b	70	b	70	b	70	N	A
6	N	A	N	A	b	70	b	70	b	70	N	A
7	b	70	N	A	b	70	b	70	b	70	N	A
8	N	A	N	A	b	70	b	70	b	70	N	A
9	b	70	b	70	b	70	b	70	b	70	b	70
10	b	70	b	70	b	70	b	70	b	70	N	A
11	b	70	N	A	b	70	b	70	b	70	b	70
12	N	A	N	A	b	70	b	70	b	70	N	A
13	N	A	N	A	b	70	b	70	b	70	N	A
14	b	70	b	70	b	70	b	70	b	70	b	70
15	b	70	b	70	b	70	b	70	b	70	N	A
16	b	70	b	70	b	70	b	70	b	70	b	70
17	N	A	N	A	b	70	b	70	b	70	N	A
18	N	A	N	A	b	70	b	70	b	70	N	A

Attribute Data ↑ ↑ Rating

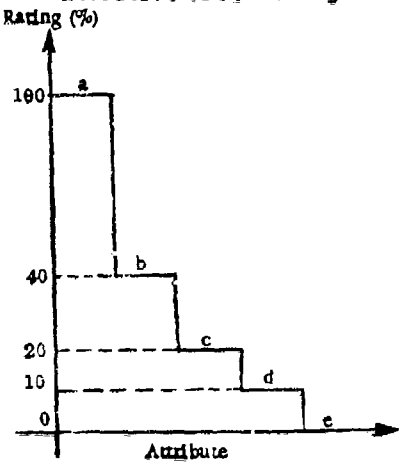
N/A Not a viable system/vessel combination

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E I - ADAPABILITY FOR SHIPBOARD INSTALLATION

245 Exhaust stack requirements for WMS waste Treatment/Disposal subsystem installation

Effectiveness Rating Function



(a) Exhaust not required.

(b) Exhaust required, size of stack relatively small and stack can be run via existing ship's stack enclosure (fiddley).

(c) Exhaust required, size of stack relatively large and stack can be run via existing ship's stack enclosure.

(d) Exhaust required, size of stack relatively small and stack cannot be run via existing ship's stack enclosure.

(e) Exhaust required, size of stack relatively large and stack cannot be run via existing ship's stack enclosure.

NOTES: 1. Electric incinerator requires small (2") exhaust.
2. Fuel incinerator requires large (10") exhaust.

Source of Data		
MSL Anal.	WMS Instal. Anal.	WMS Comp.
✓	✓	

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	a	100	a	100	a	100	a	100	c	100	c	100
2	a	100	a	100	a	100	a	100	a	100	N	A
3	e	0	N	A	e	0	c	20	c	20	N	A
4	a	100	N	A	a	100	a	100	a	100	N	A
5	N	A	N	A	a	100	a	100	a	100	N	A
6	N	A	N	A	a	100	a	100	a	100	N	A
7	e	0	N	A	e	0	c	20	e	0	N	A
8	N	A	N	A	e	0	c	20	e	0	N	A
9	a	100	a	100	a	100	a	100	a	100	a	100
10	e	0	e	0	e	0	c	20	c	20	N	A
11	a	100	N	A	a	100	a	100	a	100	a	100
12	N	A	N	A	a	100	a	100	a	100	N	A
13	N	A	N	A	e	0	c	20	e	0	N	A
14	a	100	a	100	a	100	a	100	a	100	a	100
15	e	0	e	0	e	0	c	20	c	20	N	A
16	a	100	a	100	a	100	a	100	a	100	a	100
17	N	A	N	A	a	100	a	100	a	100	N	A
18	N	A	N	A	e	0	c	20	e	0	N	A

Attribute Data ↓ ↓ Rating

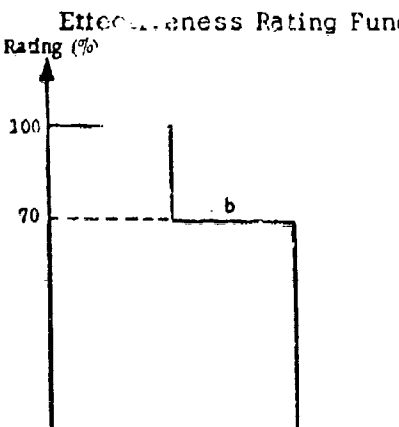
N/A - Not a viable system/vessel combination

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E I - ADAPABILITY FOR SHIPBOARD INSTALLATION

25	Ease of installing WMS support equipment

Effectiveness Rating Function



(a) No support equipn ent required.

(b) Some support equipment required but easy to install

(c) Much support equipment required and difficult to install

Examples:

- Firefighting system must be installed with incinerator.
- Bilge alarm required if large tank is installed above bilge.
- Compressor required on vessels that do not already have one.
- Detectors of toxic or noxious gasses should be installed with any system that, as an inherent design feature, uses such gases in processing wastes.

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
✓	✓	

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	b	70	b	70	b	70	b	70	b	70	b	70
2	b	70	b	70	b	70	b	70	b	70	N	A
3	b	70	N	A	b	70	b	70	b	70	N	A
4	b	70	N	A	b	70	b	70	b	70	N	A
5	N	A	N	A	b	70	b	70	b	70	N	A
6	N	A	N	A	b	70	b	70	b	70	N	A
7	b	70	N	A	b	70	b	70	b	70	N	A
8	N	A	N	A	b	70	b	70	b	70	N	A
9	b	70	b	70	b	70	b	70	b	70	b	70
10	b	70	b	70	b	70	b	70	b	70	N	A
11	b	70	N	A	b	70	b	70	b	70	b	70
12	N	A	N	A	b	70	b	70	b	70	N	A
13	N	A	N	A	b	70	b	70	b	70	N	A
14	b	70	b	70	b	70	b	70	b	70	b	70
15	b	70	b	70	b	70	b	70	b	70	N	A
16	b	70	b	70	b	70	b	70	b	70	b	70
17	N	A	N	A	b	70	b	70	b	70	N	A
18	N	A	N	A	b	70	b	70	b	70	N	A

Attribute Data ↑ ↑ Rating

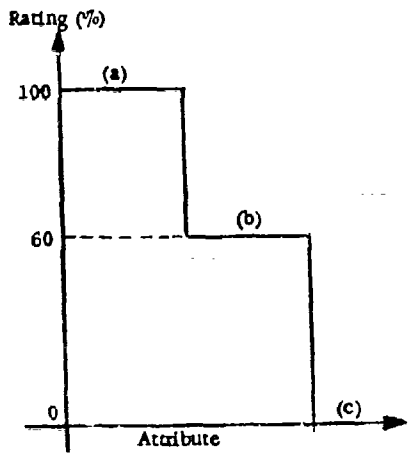
N/A - Not a viable system/vessel combination

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E I - ADAPTABILITY FOR SHIPBOARD INSTALLATION

26	Ease of compensating for added weight of WMS

Effectiveness Rating Function



(a) No or minimal compensation for added weight required.

(b) Moderate compensation for added weight required.

(c) Extensive compensation for added weight required.

Source of Data		
MSD Anal.	WMS Install. Anal. ✓	WMS Cost Anal.

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	b	60	a	100	c	0	c	0	a	100	a	100
2	b	60	a	100	b	60	b	60	a	100	N	A
3	b	60	N	A	b	60	b	60	a	100	N	A
4	c	0	N	A	b	60	b	60	b	60	N	A
5	N	A	N	A	b	60	b	60	a	100	N	A
6	N	A	N	A	b	60	b	60	a	100	N	A
7	c	0	N	A	b	60	b	60	a	100	N	A
8	N	A	N	A	b	60	b	60	a	100	N	A
9	b	60	a	100	b	60	b	60	a	100	b	60
10	b	60	b	60	c	0	b	60	a	100	N	A
11	b	60	N	A	c	0	b	60	a	100	b	60
12	N	A	N	A	c	0	b	60	a	100	N	A
13	N	A	N	A	c	0	b	60	a	100	N	A
14	b	60	a	100	c	0	b	60	a	100	a	100
15	b	60	b	60	c	0	b	60	a	100	N	A
16	b	60	b	60	c	0	b	60	a	100	b	60
17	N	A	N	A	b	60	b	60	a	100	N	A
18	N	A	N	A	b	60	b	60	a	100	N	A

Attribute Data ↑ ↑ Rating

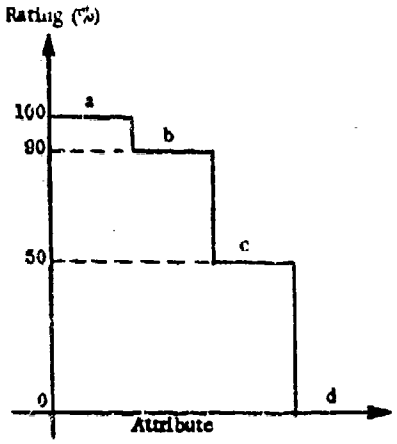
N/A - Not a viable system/vessel combination

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E I - ADAPTABILITY FOR SHIPBOARD INSTALLATION

271 Extent of SHIPALTS (permanent modifications) required for WMS installation *

Effectiveness Rating Function



(a) No SHIPALTS required.

(b) Minor SHIPALTS required.

(c) Extent of SHIPALTS required is moderate.

(d) Extensive SHIPALTS required.

*E.g., foundations, enlarged doors/hatches, increased capacity requirements for air compressor.

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
	✓	

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	b	90	a	100	c	50	d	0	b	90	a	100
2	b	90	d	0	c	50	d	0	c	50	N	A
3	b	90	N	A	c	50	d	0	c	50	N	A
4	c	50	N	A	c	50	d	0	c	50	N	A
5	N	A	N	A	c	50	d	0	b	90	N	A
6	N	A	N	A	c	50	d	0	b	90	N	A
7	c	50	N	A	c	50	d	0	b	90	N	A
8	N	A	N	A	c	50	d	0	b	90	N	A
9	b	90	b	90	c	50	c	50	b	90	c	50
10	b	90	d	0	c	50	c	50	c	50	N	A
11	c	50	N	A	c	50	c	50	c	50	c	50
12	N	A	N	A	c	50	c	50	c	50	N	A
13	N	A	N	A	c	50	c	50	c	50	N	A
14	b	90	b	90	c	50	c	50	b	90	c	50
15	b	90	d	0	c	50	c	50	b	90	N	A
16	c	50	b	90	c	50	c	50	b	90	c	50
17	N	A	N	A	c	50	c	50	b	90	N	A
18	N	A	N	A	c	50	c	50	c	50	N	A

Attribute Data ↑ ↑ Rating

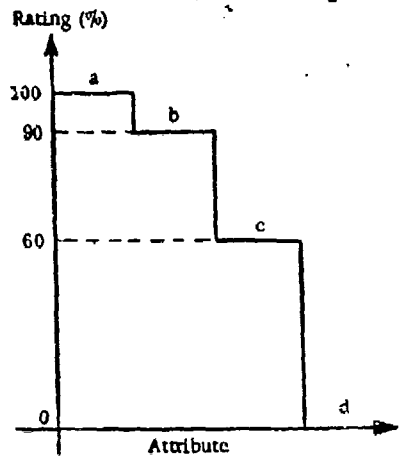
N/A - Not a viable system/vessel combination

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E I - ADAPABILITY FOR SHIPBOARD INSTALLATION

272	Extent of temporary modification* required for WMS installation

Effectiveness Rating Function



(a) No temporary modifications required.

(b) Temporary modifications required are minor.

(c) Extent of temporary modifications required is moderate.

(d) Temporary modifications required are extensive.

*E.g., cutting access openings.

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
	✓	

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	c	60	c	60	c	60	c	60	b	90	a	100
2	c	60	c	60	c	60	c	60	c	60	N	A
3	c	60	N	A	c	60	c	60	c	60	N	A
4	d	0	N	A	c	60	c	60	c	60	N	A
5	N	A	N	A	c	60	c	60	c	60	N	A
6	N	A	N	A	c	60	c	60	c	60	N	A
7	d	0	N	A	c	60	c	60	c	60	N	A
8	N	A	N	A	c	60	c	60	c	60	N	A
9	c	60	c	60	c	60	c	60	b	90	b	90
10	c	60	c	60	c	60	c	60	b	90	N	A
11	c	60	N	A	c	60	c	60	b	90	b	90
12	N	A	N	A	c	60	c	60	c	60	N	A
13	N	A	N	A	c	60	c	60	c	60	N	A
14	c	60	c	60	c	60	c	60	b	90	b	90
15	c	60	c	60	c	60	c	60	c	60	N	A
16	c	60	c	60	c	60	c	60	c	60	b	90
17	N	A	N	A	c	60	c	60	c	60	N	A
18	N	A	N	A	c	60	c	60	c	60	N	A

Attribute Data ↑ ↑ Rating

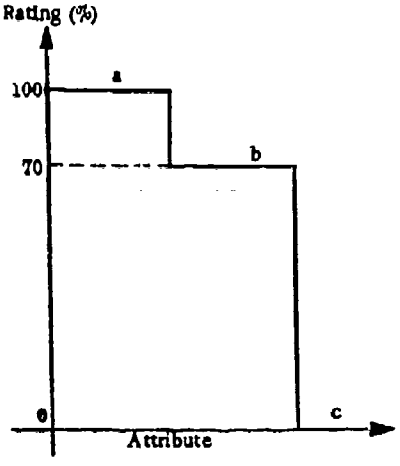
N/A - Not a viable system/vessel combination

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E I - ADAPABILITY FOR SHIPBOARD INSTALLATION

31	Effect of WMS on vessel stability

Effectiveness Rating Function



(a) No effect on existing stability characteristics of vessel.

(b) Some effect on existing stability characteristics of vessel, easily compensated for.

(c) Severe effect on existing stability characteristics of vessel, compensation requires extensive modifications to vessel (e.g., no tankage in Point Herron).

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
	✓	

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	a	100	a	100	a	100	a	100	a	100	a	100
2	a	100	a	100	a	100	a	100	a	100	N	A
3	a	100	N	A	a	100	a	100	a	100	N	A
4	a	100	N	A	a	100	a	100	a	100	N	A
5	N	A	N	A	a	100	a	100	a	100	N	A
6	N	A	N	A	a	100	a	100	a	100	N	A
7	a	100	N	A	a	100	a	100	a	100	N	A
8	N	A	N	A	a	100	a	100	a	100	N	A
9	a	100	a	100	a	100	a	100	a	100	c	0
10	a	100	a	100	a	100	a	100	a	100	N	A
11	a	100	N	A	a	100	a	100	a	100	c	0
12	N	A	N	A	a	100	a	100	a	100	N	A
13	N	A	N	A	a	100	a	100	a	100	N	A
14	a	100	a	100	a	100	a	100	a	100	a	100
15	a	100	a	100	a	100	a	100	a	100	N	A
16	a	100	a	100	a	100	a	100	a	100	c	0
17	N	A	N	A	a	100	a	100	a	100	N	A
18	N	A	N	A	a	100	a	100	a	100	N	A

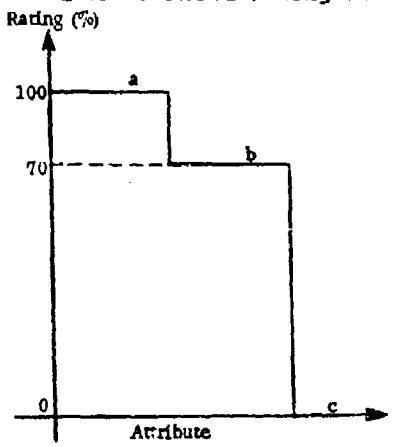
Attribute Data ↑ ↑ Rating

N/A - Not a viable system/vessel combination

M/E I - ADAPABILITY FOR SHIPBOARD INSTALLATION

32	Effect of WMS on vessel trim and list

Effectiveness Rating Function



(a) No effect on trim or on list.

(b) Some easily compensated for effect on trim or list.

(c) Compensation for effect on trim or list requires extensive modification to vessel.

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
	✓	

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	a	100	a	100	a	100	b	70	a	100	a	100
2	a	100	a	100	a	100	b	70	a	100	N	A
3	a	100	N	A	a	100	b	70	a	100	N	A
4	a	100	N	A	a	100	b	70	b	70	N	A
5	N	A	N	A	a	100	b	70	b	70	N	A
6	N	A	N	A	a	100	b	70	b	70	N	A
7	a	100	N	A	a	100	b	70	b	70	N	A
8	N	A	N	A	a	100	b	70	a	100	N	A
9	a	100	a	100	a	100	b	70	a	100	C	0
10	a	100	a	100	a	100	b	70	a	100	N	A
11	a	100	N	A	a	100	b	70	a	100	C	0
12	N	A	N	A	a	100	b	70	a	100	N	A
13	N	A	N	A	a	100	b	70	a	100	N	A
14	a	100	a	100	a	100	b	70	a	100	a	100
15	a	100	a	100	a	100	b	70	a	100	N	A
16	a	100	a	100	a	100	b	70	a	100	C	0
17	N	A	N	A	a	100	b	70	b	70	N	A
18	N	A	N	A	a	100	b	70	a	100	N	A

Attribute Data ↑ ↑ Rating

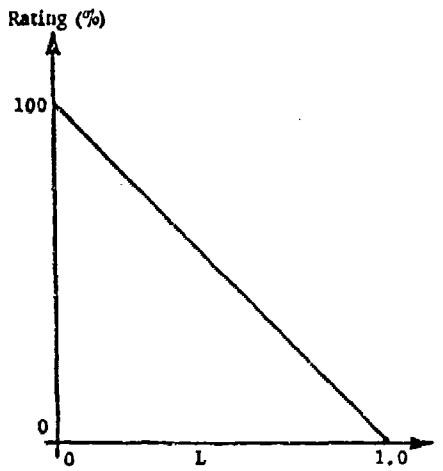
N/A - Not a viable system/vessel combination

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E I - ADAPABILITY FOR SHIPBOARD INSTALLATION

33	Effect of WMS on normal range of vessel

Effectiveness Rating Function



$$R_{1v}(\%) = 100 - 100L \quad 0 \le L \le 1.0$$
$$= 0 \quad L > 1.0$$

$L = \frac{F}{C_F} + \frac{W}{C_W}$ If vessel uses stored water

$L = \frac{F + \frac{W}{20}}{C_F}$ If vessel can generate fresh water

$R_{1v}(\%)$ - Rating (%) of ith viable candidate WMS on vessel v

(Continued)

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
	✓	✓

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	0, 0	100	0, 0	100	0, 0	100	0, 0	0	0, 0	100	0, 0	100
2	0, 0	100	0, 0	100	0, 0	100	0, 0	0	0, 0	100	N	A
3	401, 0	100	N	A	376, 0	97	176, 0	0	37, 0	100	N	A
4	0, 0	100	N	A	0, 0	100	0, 0	0	0, 0	100	N	A
5	N	A	N	A	0, 0	100	0, 0	0	0, 0	100	N	A
6	N	A	N	A	0, 0	100	0, 0	0	0, 0	100	N	A
7	537, 0	100	N	A	504, 0	96	236, 0	0	50, 0	100	N	A
8	N	A	N	A	504, 0	96	236, 0	0	50, 0	100	N	A
9	0, 881	100	0, 644	100	0, 880	97	0, 374	0	0, 79	99	0, 50	93
10	521, 881	100	363, 644	99	504, 880	93	236, 374	0	50, 79	99	N	A
11	0, 881	100	N	A	0, 880	97	0, 374	0	0, 79	99	0, 50	93
12	N	A	N	A	0, 880	97	0, 374	0	0, 79	99	N	A
13	N	A	N	A	504, 880	93	236, 374	0	50, 79	99	N	A
14	0, 852	100	0, 593	100	0, 799	97	0, 374	0	0, 79	99	0, 50	93
15	521, 852	100	363, 593	99	504, 799	93	236, 374	0	50, 79	99	N	A
16	0, 852	100	0, 593	100	0, 799	97	0, 374	0	0, 79	99	0, 50	93
17	N	A	N	A	0, 799	97	0, 374	0	0, 79	99	N	A
18	N	A	N	A	504, 799	93	236, 374	0	50, 79	99	N	A

Attribute Data ↑ ↑ Rating

N/A - Not a viable system/vessel combination

L - Range limit index due to WMS consumption of fuel and/or fresh water for i^{th} viable candiate WMS on vessel v.

F - Fuel consumption (gallons) of ith viable candidate WMS on vessel v during maximum holding time period for vessel.

W - Fresh water consumption (gallons) of ith viable candidate WMS on vessel v during maximum holding time for vessel.

C_F - Remaining gallons of fuel after maximum holding time.

C_W - Remaining gallons of fresh water after maximum holding time

Data given in the form:
F, W

VESSEL FUEL OIL AND FRESH WATER CAPACITIES AND CONSUMPTION RATES

Vessel	Required Maximum Holding Time (Hrs)	FRESH WATER				FUEL OIL		
		Capacity (Gals)	Usage Rate (Gals/Day)	Generation Rate (Gals/Day)	Remaining Gallons(7) After Max. Hold. Time	Capacity (Gals)	Usage Rate (Gals/Day)	Remaining Gallons(8) After Max. Hold. Time
Gallatin (378')	97.5	17,794	6,500	7,200	17,794	215,500 (2)	3,000	203,370
Vigorous (210')	172.0	7,700	2,000	2,500	7,700	42,000	1,800	29,094
Firebush (180')	277.9	52,995 (3)	2,300	0	26,361 (3)	27,875 (3)	1,300	12,821
Pamlico (160') New Construction	501.0	19,255 (1)	600	0	6,730 (4)	6,349	500 (5)	0 (6)
White Sage (133')	65.5	10,066	135	0	9,697	12,864	720	10,898
Point Herron (82')	99.0	1,385	150	0	765	2,000	150	1,380

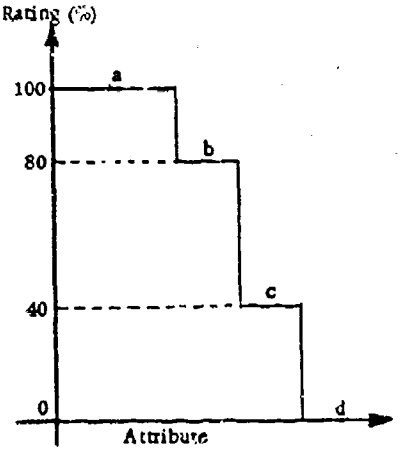
(1) Does Not Include 13,028 Gals of Cargo Water
(2) After ShipAlt Removal of Flume Tank
(3) Firebush supplies Lighthouses with Fresh Water and Fuel as follows:
  (a) Ambrose - Quarterly: 20,000 gals water, 10,000 gals fuel oil
  (b) Execution Rock - Every 2 months: 1,500 gals water, no fuel oil
  (c) Throggs Neck - Every 2 months: 1,200 gals water, 1,200 gals fuel oil
  These are taken directly from vessels tanks, there are no separate cargo tanks.
(4) This figure includes water used for flushing since Pamlico is currently outfitted with a Colt Industries Vacuum Collection System - which utilizes fresh water flush.
(5) This figure was obtain by assuming a typical operational profile of 3 days transit out, 3 days on station, 3 days return transit. Transit fuel consumption is assumed to be 600 gallons per day, and on-station 300 gallon per day.
(6) Pamlico fuel capacity is insufficient to sustain ship operation for projected required maximum holding time.
(7) Designated by C_W.
(8) Designated by C_F.

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E I - ADAPABILITY FOR SHIPBOARD INSTALLATION

34	Degree of space trade-off/reallocation required for WMS installation

Effectiveness Rating Function



(a) No space trade-off/reallocation required.

(b) Minimal degree of space trade-off/reallocation required.

(c) Moderate degree of space trade-off/reallocation required.

(d) High degree of space trade-off/reallocation required.

Source of Data		
MSE Anal.	WMS Install. Anal.	WMS Cost Anal.
	✓	

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	b	80	a	100	a	100	b	80	a	100	a	100
2	b	80	a	100	a	100	b	80	a	100	N	A
3	b	80	N	A	a	100	b	80	a	100	N	A
4	b	80	N	A	b	80	b	80	a	100	N	A
5	N	A	N	A	b	80	b	80	a	100	N	A
6	N	A	N	A	b	80	b	80	a	100	N	A
7	b	80	N	A	b	80	b	80	a	100	N	A
8	N	A	N	A	b	80	b	80	a	100	N	A
9	b	80	a	100	b	80	b	80	a	100	b	80
10	b	80	a	100	c	40	b	80	a	100	N	A
11	b	80	N	A	c	40	b	80	a	100	b	80
12	N	A	N	A	c	40	b	80	a	100	N	A
13	N	A	N	A	c	40	b	80	a	100	N	A
14	b	80	a	100	a	100	b	80	a	100	b	80
15	b	80	a	100	b	80	b	80	a	100	N	A
16	b	80	a	100	c	40	b	80	a	100	b	80
17	N	A	N	A	d	0	b	80	a	100	N	A
18	N	A	N	A	d	0	b	80	a	100	N	A

Attribute Data ↑ ↑ Rating

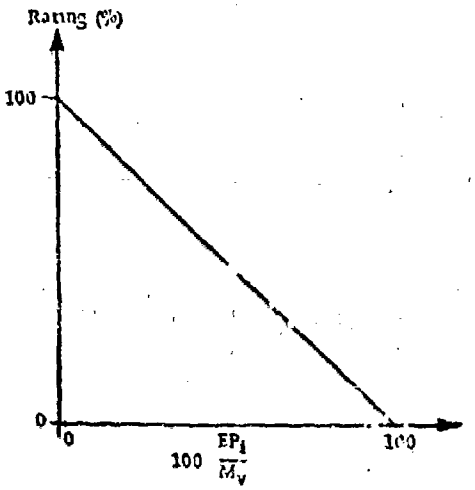
N/A - Not a viable system/vessel combination

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E I - ADAPABILITY FOR SHIPBOARD INSTALLATION

351	Amount of WMS consumption of vessel's electric power* (relative)

Effectiveness Rating Function



$$R_{iv}(\%) = 100 - 100\frac{EP_i}{M_v} \qquad 0 \le \frac{EP_i}{M_v} \le 1.0$$

$R_{iv}(\%)$ - Rating (%) of ith viable candidate WMS on vessel v

EP_i - Annual consumption of electric power (Kwh/Year) of ith viable candidate WMS on vessel v based on projected WMS utilization

M_v - Maximum value of EP_i for all viable WMS candidates for a given vessel v

* includes energy for pumping flush medium and cooling water.

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
		✓

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	350	99	107	99	127	99	53	100	48	99	8	99
2	1978	97	488	95	494	98	403	97	407	95	N	A
3	2497	96	N	A	736	97	569	96	489	94	N	A
4	8330	80	N	A	5250	79	11345	25	4089	49	N	A
5	N	A	N	A	10,344	59	11321	25	4089	49	N	A
6	N	A	N	A	10,360	59	11329	25	4089	49	N	A
7	18,496	73	N	A	9538	62	13795	9	4079	49	N	A
8	N	A	N	A	14,631	41	13768	9	5506	32	N	A
9	25756	62	8609	5	7206	71	1359	91	2163	73	527	41
10	27910	59	(9043)	0	8117	67	3807	75	3579	55	N	A
11	(67,895)	0	N	A	(24,974)	0	11,515	24	(8038)	0	889	0
12	N	A	N	A	17,439	30	12635	16	6195	23	N	A
13	N	A	N	A	16,581	34	(15080)	0	7609	5	N	A
14	848	99	311	97	290	99	92	99	2987	63	38	96
15	3002	96	744	92	1201	95	2540	83	1533	81	N	A
16	42,987	37	8779	3	18,058	28	10,248	32	5992	25	403	55
17	N	A	N	A	10,523	58	11363	25	4148	48	N	A
18	N	A	N	A	9665	61	13813	8	5564	31	N	A

Attribute Data ↑ ↑ Rating

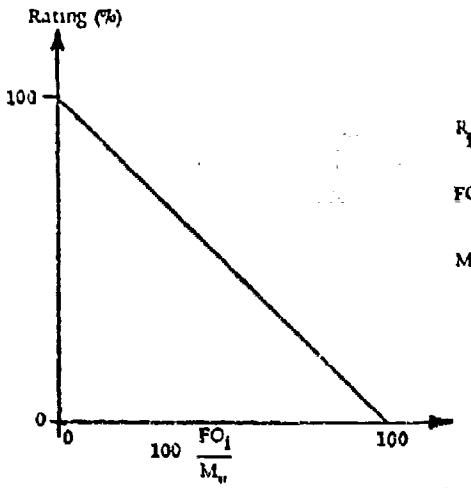
N/A - Not a viable system/vessel combination

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E I - ADAPABILITY FOR SHIPBOARD INSTALLATION

352 **Amount of WMS consumption of vessel's fuel oil (relative)**

Effectiveness Rating Function



$$R_{iv}(\%) = 100 - 100\,\frac{FO_i}{M_v} \qquad 0 \le \frac{FO_i}{M_v} \le 1.0$$

$R_{iv}(\%)$ - Rating (%) of ith viable candidate on vessel v

FO_i - Annual consumption of fuel oil (Gals/Year) of ith viable candidate WMS on vessel v based on projected WMS utilization

M_v - Maximum value of FO_i for all viable WMS candidates for a given vessel v

Source of Data		
NSD Anal.	WMS Install. Anal.	WMS Conc Anal
		✓

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	0	100	0	100	0	100	0	100	0	100	0	100
2	0	100	0	100	0	100	0	100	0	100	N	A
3	3967	25	N	A	1673	25	956	25	553	25	N	A
4	0	100	N	A	0	100	0	100	0	100	N	A
5	N	A	N	A	0	100	0	100	0	100	N	A
6	N	A	N	A	0	100	0	100	0	100	N	A
7	(5309)	0	N	A	(2239)	0	(1280)	0	(740)	0	N	A
8	N	A	N	A	2239	0	1280	0	740	0	N	A
9	0	100	0	100	0	100	0	100	0	100	0	100
10	5151	3	(1035)	0	2239	0	1280	0	740	0	N	A
11	0	100	N	A	0	100	0	100	0	100	0	100
12	N	A	N	A	0	100	0	100	0	100	N	A
13	N	A	N	A	2239	0	1280	0	740	0	N	A
14	0	100	0	100	0	100	0	100	0	100	0	100
15	5151	3	1035	0	2239	0	1280	0	740	0	N	A
16	0	100	0	100	0	100	0	100	0	100	0	100
17	N	A	N	A	0	100	0	100	0	100	N	A
18	N	A	N	A	0	100	1280	0	740	0	N	A

Attribute Data ↑ ↑ Rating

N/A - Not a viable system/vessel combination

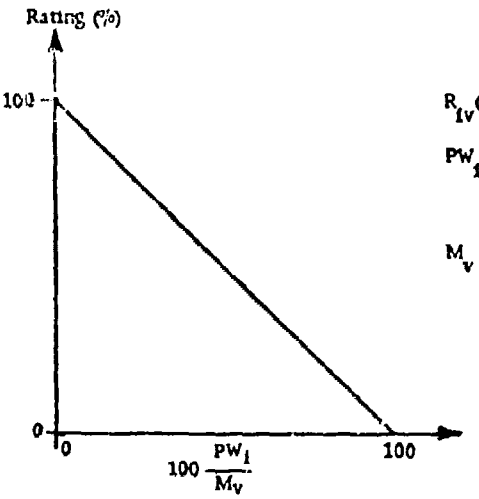
EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E I - ADAPABILITY FOR SHIPBOARD INSTALLATION

353	Amount of WMS consumption of vessel's potable water (relative)

Effectiveness Rating Function

$$R_{iv}(\%) = 100 - 100\frac{PW_i}{M_v} \quad \left| \quad 0 \leq \frac{PW_i}{M_v} \leq 1.0 \right.$$



$R_{iv}(\%)$ - Rating (%) of ith viable candidate on vessel v

PW_i - Annual consumption of potable water (Gals/Year) of ith viable candidate WMS on vessel v based on projected WMS utilization

M_v - Maximum value of PW_i for all viable WMS candidates for a given vessel v

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal. ✓

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	0	100	0	100	0	100	0	100	0	100	0	100
2	0	100	0	100	0	100	0	100	0	100	N	A
3	0	100	N	A	0	100	0	100	0	100	N	A
4	0	100	N	A	0	100	0	100	0	100	N	A
5	N	A	N	A	0	100	0	100	0	100	N	A
6	N	A	N	A	0	100	0	100	0	100	N	A
7	0	100	N	A	0	100	0	100	0	100	N	A
8	N	A	N	A	0	100	0	100	0	100	N	A
9	(79117)	0	(32,777)	0	(27740)	0	(6548)	0	(10578)	0	(2190)	0
10	79117	0	32,777	0	27740	0	6548	0	10578	0	N	A
11	79117	0	N	A	27740	0	6548	0	10578	0	2190	0
12	N	A	N	A	27740	0	6548	0	10578	0	N	A
13	N	A	N	A	27740	0	6548	0	10578	0	N	A
14	76562	3	30222	8	25185	9	6548	0	10578	0	2190	0
15	76562	3	30222	8	25185	9	6548	0	10578	0	N	A
16	76562	3	30222	8	25185	9	6548	0	10578	0	2190	0
17	N	A	N	A	25185	9	6548	0	10578	0	N	A
18	N	A	N	A	25185	9	6548	0	10578	0	N	A

Attribute Data ↑ ↑ Rating

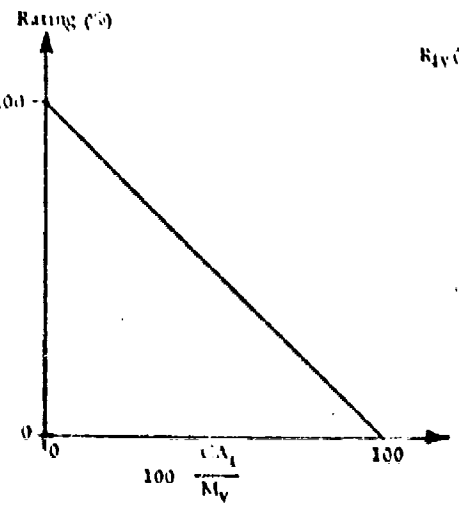
N/A - Not a viable system/vessel combination

MOP 1 - ADAPABILITY FOR SHIPBOARD INSTALLATION

354 Amount of WMS consumption of vessel's compressed air (relative)

Effectiveness Rating Function

$$R_{iv}(\%) = 100 - 100\,\frac{CA_i}{M_v} \qquad 0 \le \frac{CA_i}{M_v} \le 1.0$$



$R_{iv}(\%)$ = Rating (%) of ith viable candidate on vessel v

CA_i = Annual consumption of compressed air (SCFM x 10^6/Year) of ith viable candidate WMS on vessel v based on projected WMS utilization

M_v = Maximum value of CA_i for all viable WMS candidates for a given vessel v

NOTE: Only the SCFM usage of WMS subsystems is considered here; the pressure at which air is used is not considered.

Source of Data

MSO Anal.	WMS Install. Anal.	WMS Con Anal

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	(7.37)	0	(1.03)	0	8.81	19	9.05	17	0.68598	0	(0.03726)	0
2	1.32	82	0.25816	75	1.65	85	1.69	85	0.12876	81	N	A
3	0	100	N	A	0	100	0	100	0	100	N	A
4	0.616	92	N	A	0.8178	93	0.7564	93	0.06	91	N	A
5	N	A	N	A	2.82	74	2.92	74	0.22089	68	N	A
6	N	A	N	A	(10.91)	0	(11.16)	0	(0.68598)	0	N	A
7	2.54	66	N	A	1.07	90	0.6138	95	0.355644	48	N	A
8	N	A	N	A	1.07	90	0.6138	95	0.355644	48	N	A
9	2.156	71	0.3528	66	2.54	77	2.84	75	0.190143	72	0.0162	57
10	0.616	92	0.1232	88	0.25	98	0.6138	95	0.355644	48	N	A
11	3.509	52	N	A	1.48	86	0.8463	92	0.490065	29	0.03024	19
12	N	A	N	A	2.54	77	2.84	75	0.190143	72	N	A
13	N	A	N	A	1.07	90	0.6138	95	0.355644	48	N	A
14	2.343	68	0.8344	19	2.82	74	2.92	74	0.220557	68	0.0207	44
15	0.616	92	0.12	88	0.25944	98	0.6138	95	0.355644	48	N	A
16	3.509	52	0.7056	31	1.48	86	0.8463	92	0.49	29	0.03024	19
17	N	A	N	A	2.82	74	2.92	74	0.58	15	N	A
18	N	A	N	A	1.07	90	0.6138	95	0.36	48	N	A

Attribute Data ↑ ↑ Rating

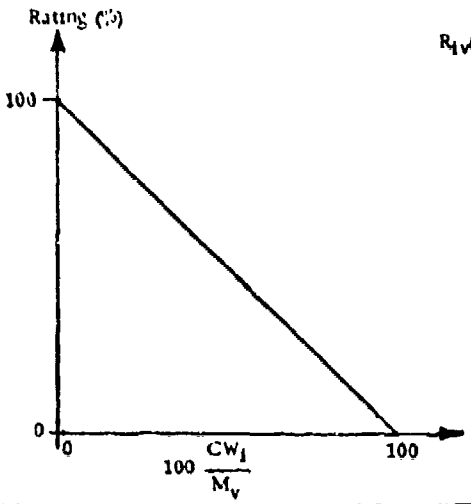
N/A - Not a viable system/vessel combination

M/E I - ADAPABILITY FOR SHIPBOARD INSTALLATION

355	Amount of WMS consumption of cooling water (relative)

Effectiveness Rating Function

$$R_{iv}(\%) = 100 - 100\,\frac{CW_i}{M_v} \qquad 0 \le \frac{CW_i}{M_v} \le 1.0$$



$R_{iv}(\%)$ = Rating (%) of ith viable candidate WMS on vessel v

CW_i = Annual consumption of cooling water (Gals/Year) of ith viable candidate WMS on vessel v based on projected WMS utilization

M_v = Maximum value of CW_i for all viable WMS candidates for a given vessel v

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
		✓

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	0	100	0	100	0	100	0	100	0	100	0	100
2	0	100	0	100	0	100	0	100	0	100	N	A
3	0	100	N	A	0	100	0	100	0	100	N	A
4	73,584	0	N	A	92,637	50	203,670	0	72,927	0	N	A
5	N	A	N	A	185,274	0	203,670	0	72,927	0	N	A
6	N	A	N	A	185,274	0	203,670	0	72,927	0	N	A
7	73,584	0	N	A	92,637	50	203,670	0	72,927	0	N	A
8	N	A	N	A	185,274	0	203,670	0	72,927	0	N	A
9	0	100	0	100	0	100	0	100	0	100	0	100
10	0	100	0	100	0	100	0	100	0	100	N	A
11	0	100	N	A	0	100	0	100	0	100	0	100
12	N	A	N	A	185,274	0	203,670	0	72,927	0	N	A
13	N	A	N	A	92,637	50	203,670	0	72,927	0	N	A
14	0	100	0	100	0	100	0	100	0	100	0	100
15	0	100	0	100	0	100	0	100	0	100	N	A
16	0	100	0	100	0	100	0	100	0	100	0	100
17	N	A	N	A	185,274	0	203,670	0	72,927	0	N	A
18	N	A	N	A	92,637	50	203,670	0	72,927	0	N	A

Attribute Data ↑ ↑ Rating

N/A - Not a viable system/vessel combination

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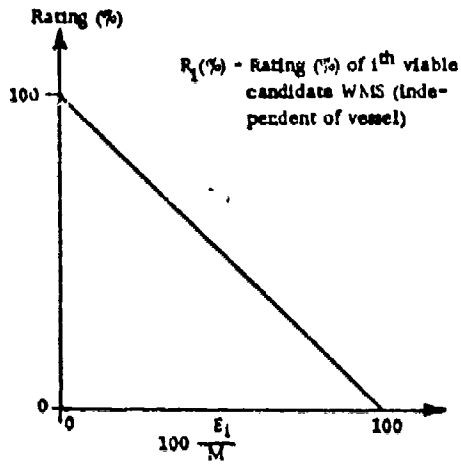
EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E II - PERFORMANCE

11	WMS per capita energy consumption (relative)

Effectiveness Rating Function



$$R_{iv}(\%) = 100 - 100\,\frac{E_i}{M} \qquad 0 \le \frac{E_i}{M} \le 1.0$$

$R_i(\%)$ - Rating (%) of ith viable candidate WMS (independent of vessel)

E_i - Annual per capita energy consumption (Kwh/Year) of ith viable candidate WMS on vessel v based on projected WMS utilization

M - Maximum value of E_i for all viable WMS candidates for any vessel

NOTE: Includes electric power; power for ventilation; compressed air; pumping flush medium and cooling water; fuel; fuel for fresh water generated aboard vessel.

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
		✓

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

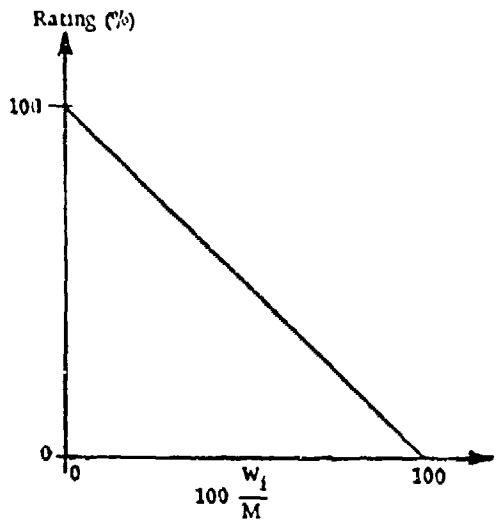
WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	12	100	5	100	49	98	141	94	10	100	1	100
2	15	99	9		15	99	49	98	25	99	N	A
3	365	86	N	A	450	82	1000	60	367	85	N	A
4	56	98	N	A	107	96	882	65	195	92	N	A
5	N	A	N	A	217	91	910	64	197	92	N	A
6	N	A	N	A	281	89	1015	60	202	92	N	A
7	592	76	N	A	805	68	2421	4	747	70	N	A
8	N	A	N	A	908	64	2415	4	747	70	N	A
9	221	91	178	93	156	94	147	94	103	96	62	98
10	(679)	73	411	84	752	70	1647	34	656	74	N	A
11	520	79	N	A	531	79	152	94	408	84	116	95
12	N	A	N	A	361	86	1014	60	295	88	N	A
13	N	A	N	A	(947)	62	(2514)	0	(847)	66	N	A
14	45	98	27	99	18	99	51	98	8	100	4	100
15	514	80	(256)	90	613	76	1549	38	559	78	N	A
16	344	86	189	92	393	84	859	66	310	88	54	98
17	N	A	N	A	223	91	918	63	225	91	N	A
18	N	A	N	A	809	68	2417	4	749	70	N	A

Attribute Data ↑ ↑ Rating

N/A - Not a viable system/vessel combination

12	WMS per capita wet weight (relative)

Effectiveness Rating Function



$$R_{iv}(\%) = 100 - 100\,\frac{W_i}{M} \qquad 0 \le \frac{W_i}{M} \le 1.0$$

R_{iv} (%) - Rating (%) of ith viable candidate WMS on vessel v

W_i - Total per capita wet weight (lb.) of ith viable candidate WMS (including drain piping) on vessel v

M - Maximum value of W_i for all viable WMS candidates for any vessel

* Drain piping material is assumed to be copper-nickel (Cu-Ni).

Source of Data		
MSD Anal.	WMS Install. Anal. ✓	WMS Cost Anal.

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	(1040)	88	570	93	1626	81	(8585)	0	(1692)	81	585	93
2	657	92	355	96	496	94	6356	26	1467	83	N	A
3	591	93	N	A	826	90	6106	29	1493	83	N	A
4	634	93	N	A	1353	84	6220	28	1574	82	N	A
5	N	A	N	A	996	88	1909	78	719	92	N	A
6	N	A	N	A	(2108)	75	4368	49	1068	88	N	A
7	662	92	N	A	1591	81	6233	27	1074	87	N	A
8	N	A	N	A	593	93	1220	86	670	92	N	A
9	695	92	472	95	1333	84	6512	24	1387	84	(937)	89
10	682	92	419	95	1891	78	5853	32	1467	83	N	A
11	596	93	N	A	1873	78	5577	35	1333	84	788	91
12	N	A	N	A	1417	83	2538	70	746	91	N	A
13	N	A	N	A	703	92	1105	87	672	92	N	A
14	858	90	(641)	93	1231	86	6535	24	1442	83	920	89
15	867	90	440	95	1785	79	5865	32	1462	83	N	A
16	558	94	321	96	1751	80	5619	35	1351	84	763	91
17	N	A	N	A	1152	87	2559	70	818	90	N	A
18	N	A	N	A	601	93	1108	87	718	92	N	A

Attribute Data ↑ ↑ Rating

N/A - Not a viable system/vessel combination

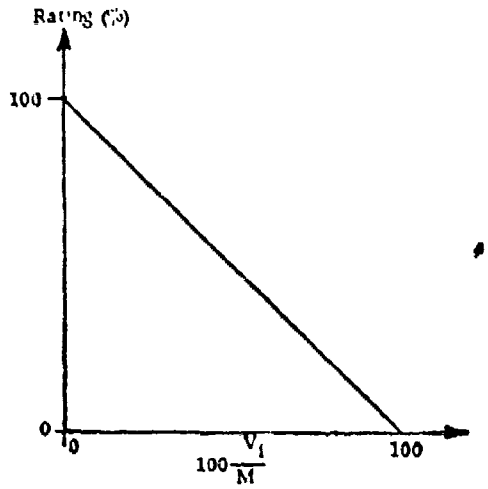
EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E II - PERFORMANCE

13	WMS per capita volume (relative)

Effectiveness Rating Function

$$R_{iv}(\%) = 100 - 100\frac{V_i}{M} \qquad 0 \le \frac{V_i}{M} \le 1.0$$



R_{iv} (%) = Rating (%) of ith viable candidate WMS on vessel v

V_i = Total per capita volume (ft^3) of ith viable candidate WMS (including drain piping) on vessel v

M = Maximum value of V_i for all viable WMS candidates for any vessel

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
	✓	

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	29.0	90	20.9	93	35.9	88	279.6	3	89.7	69	51.3	87
2	29.8	90	21.1	93	30.2	90	287.3	1	100.7	65	N	A
3	(31.5)	89	N	A	60.7	79	(289.3)	0	103.8	64	N	A
4	29.5	90	N	A	62.4	78	289.3	0	109.6	62	N	A
5	N	A	N	A	64.8	78	149.8	48	92.2	98	N	A
6	N	A	N	A	52.7	82	224.6	22	117.1	60	N	A
7	27.7	90	N	A	55.3	81	281.6	3	(137.3)	53	N	A
8	N	A	N	A	40.9	86	73.8	74	89.7	69	N	A
9	28.8	90	21.2	93	58.7	80	271.1	6	103.9	64	89.9	69
10	29.1	90	21.8	92	52.9	82	199.8	31	97.9	66	N	A
11	29.5	90	N	A	55.9	81	187.8	35	91.4	68	95.4	67
12	N	A	N	A	(90.8)	69	193.8	33	98.9	66	N	A
13	N	A	N	A	71.8	75	124.8	57	80.6	72	N	A
14	29.3	90	21.4	93	45.1	84	252.5	13	77.7	73	(96.4)	67
15	31.1	89	(22.0)	92	60.6	79	199.8	31	86.3	70	N	A
16	29.0	90	21.2	93	60.1	79	167.2	42	71.6	75	85.4	70
17	N	A	N	A	87.5	70	187.9	35	116.6	60	N	A
18	N	A	N	A	65.7	77	118.9	59	88.9	69	N	A

Attribute Data ↑ ↑ Rating

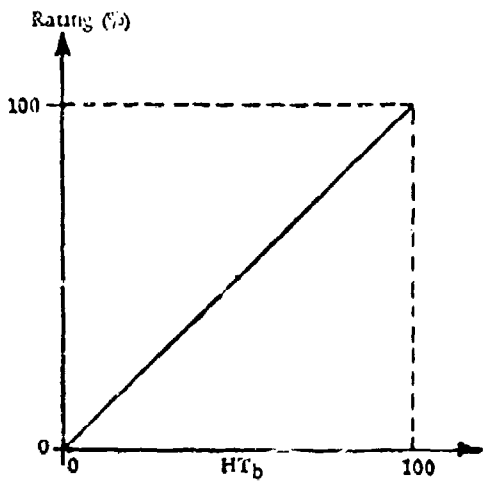
N/A = Not a viable system/vessel combination

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E II - PERFORMANCE

21	Adequacy of WMS black water holding times

Effectiveness Rating Function



$R_{Iv}(\%) = HT_b \quad 0 \leq HT_b \leq 100$

$R_{Iv}(\%)$ - Rating (%) of ith viable candidate WMS on vessel v

HT_b - % of required black water holding time met by WMS

Vessel	Maximum Holding Time Required (Hours) *
GALLATIN	97.5
VIGOROUS	172.0
FIREBUSH	277.9
PAMLICO	501.0
WHITE SAGE	65.5
POINT HERRON	99.0

* Based on vessel mission profiles. A WMS which employs an incinerator or evaporator is considered to meet 100% of the required holding time. The holding time of a WMS which employs a holding tank (for wastewater or sludge) is determined by the ratio of available tank capacity to required capacity.

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
	✓	

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

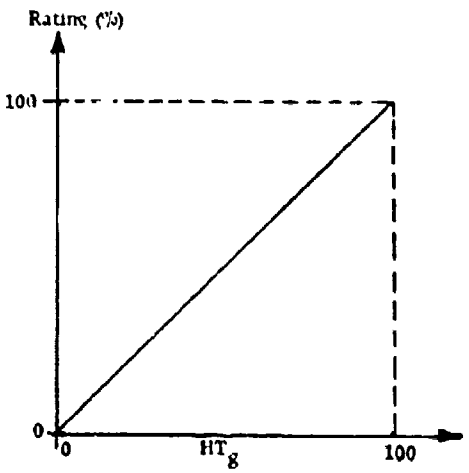
WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	100	100	40	40	100	100	100	100	100	100	58	58
2	100	100	53	53	100	100	100	100	100	100	N	A
3	100	100	N	A	100	100	100	100	100	100	N	A
4	100	100	N	A	100	100	100	100	100	100	N	A
5	N	A	N	A	100	100	100	100	100	100	N	A
6	N	A	N	A	100	100	100	100	100	100	N	A
7	100	100	N	A	100	100	100	100	100	100	N	A
8	N	A	N	A	100	100	100	100	100	100	N	A
9	100	100	48	48	100	100	100	100	100	100	100	100
10	100	100	100	100	100	100	100	100	100	100	N	A
11	100	100	N	A	100	100	100	100	100	100	100	100
12	N	A	N	A	100	100	100	100	100	100	N	A
13	N	A	N	A	100	100	100	100	100	100	N	A
14	100	100	100	100	100	100	100	100	100	100	100	100
15	100	100	100	100	100	100	100	100	100	100	N	A
16	100	100	100	100	100	100	100	100	100	100	100	100
17	N	A	N	A	100	100	100	100	100	100	N	A
18	N	A	N	A	100	100	100	100	100	100	N	A

Attribute Data ↑ ↑ Rating

N/A - Not a viable system/vessel combination

22 Adequacy of WMS gray water holding times

Effectiveness Rating Function



$R_{iv}(\%) = HT_g \quad 0 \le HT_g \le 100$

R_{iv} (%) - Rating (%) of ith viable candidate WMS on vessel v

HT_g - % of required gray water holding time met by WMS

Vessel	Maximum Holding Time Required (Hours)*
GALLATIN	97.5
VIGOROUS	172.0
FIREBUSH	277.9
PAMLICO	501.0
WHITE SAGE	65.5
POINT HERRON	99.0

*Based on vessel mission profiles. A WMS which employs an incinerator or evaporator is considered to meet 100% of the required holding time. The holding time of WMS which employs a holding tank (for wastewater or sludge) is determined by the ratio of available tank capacity to required capacity.

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
	✓	

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	19	19	1	1	0	0	55	55	100	100	0	0
2	18	18	1	1	0	0	64	64	100	100	N	A
3	13	13	N	A	12	12	64	64	100	100	N	A
4	17	17	N	A	22	22	64	64	100	100	N	A
5	N	A	N	A	100	100	100	100	100	100	N	A
6	N	A	N	A	100	100	100	100	100	100	N	A
7	17	17	N	A	29	29	64	64	100	100	N	A
8	N	A	N	A	100	100	100	100	100	100	N	A
9	21	21	1	1	13	13	64	64	100	100	20	20
10	21	21	1	1	35	35	64	64	100	100	N	A
11	17	17	N	A	35	35	64	64	100	100	20	20
12	N	A	N	A	100	100	100	100	100	100	N	A
13	N	A	N	A	100	100	100		100	100	N	A
14	30	30	1	1	13	13	64	64	100	100	20	20
15	33	33	3	3	35	35	64	64	100	100	N	A
16	17	17	1	1	35	35	64	64	100	100	20	20
17	N	A	N	A	100	100	100	100	100	100	N	A
18	N	A	N	A	100	100	100	100	100	100	N	A

Attribute Data ↑ ↑ Rating

N/A - Not a viable system/vessel combination

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E II - PERFORMANCE

311 Effect of peak hydraulic loads* in black water stream on WMS performance

Effectiveness Rating Function

$R_{iv}(\%)$ = $GIST_b$ - If the WMS black water subsystem has a Grumman MSD, or other MSD requiring an influent surge tank
= Rating based on $Z_{C/T}$, otherwise

$R_{iv}(\%)$ = Rating (%) of ith viable candidate WMS on vessel v

* Includes instantaneous, hourly and daily loads.

NOTES: 1. A WMS gets the rating that its black water C/T subsystem would receive

2. The ability of the Grumman or other MSD requiring an influent surge tank to handle peaks depends almost entirely on the sizing of its influent surge tank; optimum sizing cannot always be provided on all vessels.

Source of Data		
MSD Anal.	WMS Install. Anal	WMS Con Anal
✓	✓	

(Continued)

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (160')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	a	100	a	100	a	100	a	100	a	100	a	100
2	b	80	b	80	b	80	b	80	b	80	N	A
3	b	80	N	A	b	80	b	80	b	80	N	A
4	100	100	N	A	100	100	100	100	100	100	N	A
5	N	A	N	A	100	100	100	100	100	100	N	A
6	N	A	N	A	a	100	a	100	a	100	N	A
7	100	100	N	A	100	100	100	100	100	100	N	A
8	N	A	N	A	100	100	100	100	100	100	N	A
9	b	80	b	80	b	80	b	80	b	80	b	80
10	b	80	b	80	b	80	b	80	b	80	N	A
11	b	80	N	A	b	80	b	80	b	80	b	80
12	N	A	N	A	b	80	b	80	b	80	N	A
13	N	A	N	A	b	80	b	80	b	80	N	A
14	a	100	a	100	a	100	a	100	a	100	a	100
15	a	100	a	100	a	100	a	100	a	100	N	A
16	a	100	a	100	a	100	a	100	a	100	a	100
17	N	A	N	A	a	100	a	100	a	100	N	A
18	N	A	N	A	100	100	100	100	100	100	N	A

Attribute Data ↑ ↑ Rating

N/A - Not a viable system/vessel combination

II - 311

$GIST_b$ - % of required influent surge tank capacity for Grumman (or other MSD requiring an influent surge tank in black water stream) provided by installation.

$Z_{C/T}$ - Peak load handling ability of WMS (black water) C/T subsystem which does not employ an influent surge tank.

Data given in the form:

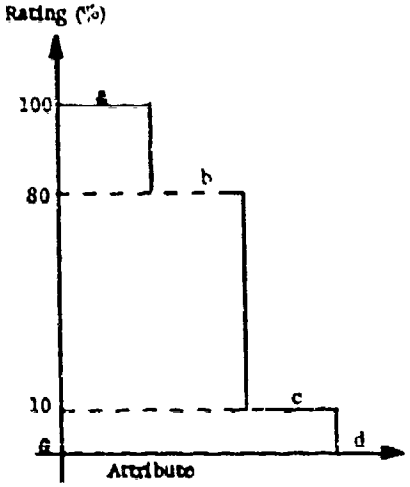
$GIST_b$ - If WMS (black water) C/T subsystem employs an influent surge tank

$Z_{C/T}$ - If WMS (black water) C/T subsystem does not employ an influent surge tank

NOTE: $Z_{C/T}$ is not vessel dependent

$GIST_b$ is vessel dependent

Definition and Corresponding Ratings for $Z_{C/T}$



(a) No significant effect of black water peaks on WMS subsystem performance.

(b) Effect of black water peaks is of short duration, with temporary implications for WMS subsystem performance, easy to overcome.

(c) Long-term effect of black water peaks, difficult to overcome, with long-term implications for WMS subsystem performance.

(d) No ability of WMS subsystem to handle black water peaks.

312 Effect of peak hydraulic loads* in gray water streams on WMS performance.

Effectiveness Rating Function

$R_{iv}(\%) = GIST_g$ - If the WMS gray water subsystem has a Grumman MSD, or other MSD requiring an influent surge tank
= Rating based on $ZG_{C/T}$, otherwise

$R_{iv}(\%)$ = Rating (%) of ith viable candidate WMS on vessel v

(Continued)

* Includes instantaneous, hourly and daily loads.

NOTES:

1. A WMS gets the rating that its gray water C/T subsystem would receive.
2. The ability of the Grumman or other MSD requiring an influent surge tank to handle peaks depends almost entirely on the sizing of its influent surge tank: optimum sizing cannot always be provided on all vessels.

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
✓	✓	

(Continued)

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	a	100	a	100	a	100	a	100	a	100	a	100
2	a	100	a	100	a	100	a	100	a	100	N	A
3	a	100	N	A	a	100	a	100	a	100	N	A
4	a	100	N	A	a	100	a	100	a	100	N	A
5	N	A	N	A	100	100	100	100	100	100	N	A
6	N	A	N	A	100	100	100	100	100	100	N	A
7	a	100	N	A	a	100	a	100	a	100	N	A
8	N	A	N	A	100	100	100	100	100	100	N	A
9	a	100	a	100	a	100	a	100	a	100	a	100
10	a	100	a	100	a	100	a	100	a	100	N	A
11	a	100	N	A	a	100	a	100	a	100	a	100
12	N	A	N	A	100	100	100	100	100	100	N	A
13	N	A	N	A	100	100	100	100	100	100	N	A
14	a	100	a	100	a	100	a	100	a	100	a	100
15	a	100	a	100	a	100	a	100	a	100	N	A
16	a	100	a	100	a	100	a	100	a	100	a	100
17	N	A	N	A	100	100	100	100	100	100	N	A
18	N	A	N	A	100	100	100	100	100	100	N	A

Attribute Data ↑ ↑ Rating

N/A - Not a viable system/vessel combination

$GIST_g$ - % of required influent surge tank capacity for Grumman (or other MSD requiring an influent surge tank in gray water stream) provided by installation.

$ZG_{C/T}$ - Peak load handling ability of non-Grumman (i.e., CHT) gray water C/T subsystem.

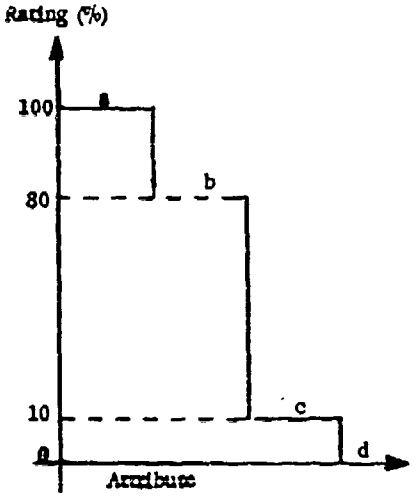
Data given in the form:

$GIST_g$ - If WMS (gray water) C/T subsystem employs an influent surge tank

$ZG_{C/T}$ - If WMS (gray water) C/T subsystem does not employ an influent surge tank

NOTE: $ZG_{C/T}$ is not vessel dependent

$GIST_g$ is vessel dependent



Definition and Corresponding Ratings for ZG_{TD}

(a) No significant effect of gray water peaks on WMS subsystem performance.

(b) Effect of gray water peaks is of short duration, with temporary implications for WMS subsystem performance, easy to overcome.

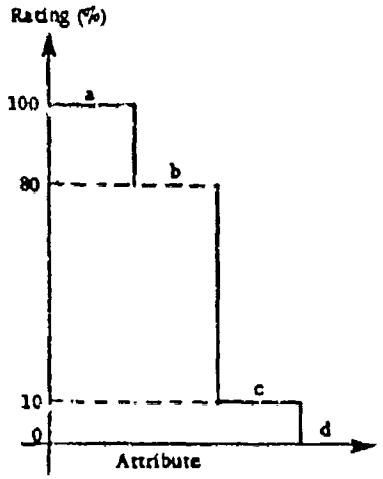
(c) Long-term effect of gray water peaks, difficult to overcome, with long-term implications for WMS subsystem performance.

(d) No ability of WMS subsystem to handle gray water peaks.

321 Effect of low flow conditions/long idle times in black water stream on WMS performance

Effectiveness Rating Function

$$R_{WMS} = \text{Min}\,(R_{C/T},\ RB_{T/D})$$



R_{WMS} = Rating for WMS

$R_{C/T}$ = Rating for (black water) C/T subsystem

$RB_{T/D}$ = Rating for black water T/D subsystem

Data given in the form (not vessel dependent):

$Z_{C/T}$, $ZB_{T/D}$ } Attribute

$R_{C/T}$, $RB_{T/D}$ } Ratings

NOTE: An example of low flow condition is when 75% of the crew is not on board for a week and usage rate by remaining 25% of crew is normal.
Long idle times are on the order of several weeks of virtually no usage of WMS.

(Continued)

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
✓		

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (130')		WHITE SAGE (133')		POINT HERRON (82')	
1					a, a	100						
2					b, b	80					N	A
3			N	A	b, b	80					N	A
4			N	A	b, b	80					N	A
5	N	A	N	A	b, b	80					N	A
6	N	A	N	A	a, a	100					N	A
7			N	A	b, b	80					N	A
8	N	A	N	A	b, b	80					N	A
9					a, a	100						
10					a, a	100					N	A
11			N	A	a, a	100						
12	N	A	N	A	a, a	100					N	A
13	N	A	N	A	a, a	100					N	A
14					a, a	100						
15					a, a	100					N	A
16					a, a	100						
17	N	A	N	A	a, a	100					N	A
18	N	A	N	A	a, a	100					N	A

Attribute Data ↑ ↑ Rating

N/A - Not a viable system/vessel combination

Definitions of $Z_{C/T}$ and $ZB_{T/D}$

(a) No significant effect of black water low flow conditions/long idle times on WMS subsystem performance.

(b) Effect of black water low flow conditions/long idle times is of short duration, with temporary implications for WMS subsystem performance, easy to overcome.

(c) Long-term effect of black water low flow conditions/long idle times, difficult to overcome, with long-term implications for WMS subsystem performance.

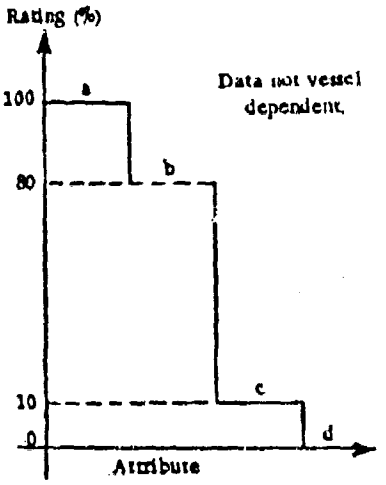
(d) No ability of WMS subsystem to handle black water low flow conditions/long idle times.

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E II - PERFORMANCE

322	Effect of low flow conditions/long idle times in gray water stream on WMS performance

Effectiveness Rating Function



(a) No significant effect of gray water low flow conditions/long idle times on WMS subsystem performance.

(b) Effect of gray water low flow conditions/long idle times is of short duration, with temporary implications for WMS subsystem performance, easy to overcome.

(c) Long-term effect of gray water low flow conditions/long idle times, difficult to overcome, with long-term implications for WMS subsystem performance.

(d) No ability of WMS subsystem to handle gray water low flow conditions/long idle times.

NOTES: (1) An example of low flow condition is when 75% of the crew is not on board for a week and usage rate by remaining 25% of crew is normal. Long idle times are on the order of several weeks of virtually no usage of WMS.

(2) WMS rating is based on the rating of the gray water T/D subsystem.

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Con Anal.
✓		

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1					a	100						
2					a	100					N	A
3			N	A	a	100					N	A
4			N	A	a	100					N	A
5	N	A	N	A	b	80					N	A
6	N	A	N	A	b	80					N	A
7			N	A	a	100					N	A
8	N	A	N	A	b	80					N	A
9					a	100						
10					a	100					N	A
11			N	A	a	100						
12	N	A	N	A	b	80					N	A
13	N	A	N	A	b	80					N	A
14					a	100						
15					a	100					N	A
16					a	100						
17	N	A	N	A	b	80					N	A
18	N	A	N	A	b	80					N	A

Attribute Data ↑ ↑ Rating

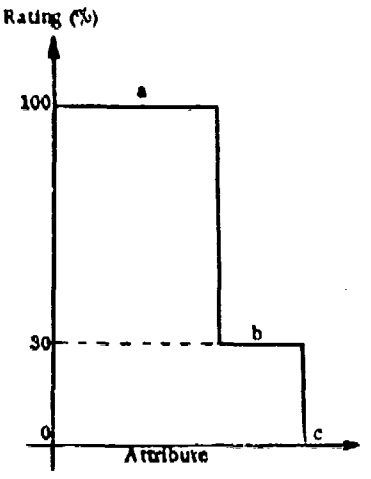
N/A - Not a viable system/vessel combination

M/E II - PERFORMANCE

331 Ability of black water portion of WMS to handle additional personnel (on a long-term basis)*

Effectiveness Rating Function

$R_{WMS} = \text{Min}(R_{C/T}, RB_{T/D})$



R_{WMS} - Rating for WMS

$R_{C/T}$ - Rating for (black water) C/T subsystem

$RB_{T/D}$ - Rating for black water T/D subsystem. If this subsystem employs a holding tank it receives its full rating only if 100% of the required tank capacity is met by the installation (i.e., if $HTC_b = 100\%$). Otherwise, its rating is 0.

HTC_b - % of required black water (or sludge) holding tank capacity provided by installation.

(Continued)

* Resulting in a long term increase in average black water stream hydraulic loading. The ability of a WMS which employs a black water (or sludge) holding tank to handle additional personnel may be determined by the size of that tank; optimum sizing cannot always be provided on the vessel.

Source of Data		
NSID Anal.	WMS Install. Anal.	WMS Con Anal.
✓	✓	

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	/ ,100	30	/ ,40	0	a/b, 100	30	/ ,100	30	/ ,100	30	/ ,58	0
2	/ ,100	30	/ ,53	0	a/b, 100	30	/ ,100	30	/ ,100	30	N	A
3	/	30	N	A	a/b	30	/	30	/	30	N	A
4	/ ,100	30	N	A	a/b, 100	30	/ ,100	30	/ ,100	30	N	A
5	N	A	N	A	a/b, 100	30	/ ,100	30	/ ,100	30	N	A
6	N	A	N	A	a/b, 100	30	/ ,100	30	/ ,100	30	N	A
7	/	100	N	A	a/a	100	/	100	/	100	N	A
8	N	A	N	A	a/a	100	/	100	/	100	N	A
9	/ ,100	30	/ ,48	0	a/b, 100	30	/ ,100	30	/ ,100	30	/ ,100	30
10	/	100	/	100	a/a	100	/	100	/	100	N	A
11	/	30	N	A	a/b	30	/	30	/	30	/	30
12	N	A	N	A	a/b, 100	30	/ ,100	30	/ ,100	30	N	A
13	N	A	N	A	a/a	100	/	100	/	100	N	A
14	/ ,100	30	/ ,100	30	a/b, 100	30	/ ,100	30	/ ,100	30	/ ,100	30
15	/	100	/	100	a/a	100	/	100	/	100	N	A
16	/	30	/	30	a/b	30	/	30	/	30	/	30
17	N	A	N	A	a/b, 100	30	/ ,100	30	/ ,100	30	N	A
18	N	A	N	A	a/a	100	/	100	/	100	N	A

Attribute Data → ← Rating

N/A - Not a viable system/vessel combination

Data given in the form:

$Z_{C/T}$ / $ZB_{T/D}$ } Attribute
$R_{C/T}$, $RB_{T/D}$ } Ratings

If WMS black water T/D subsystem does not employ a holding tank.

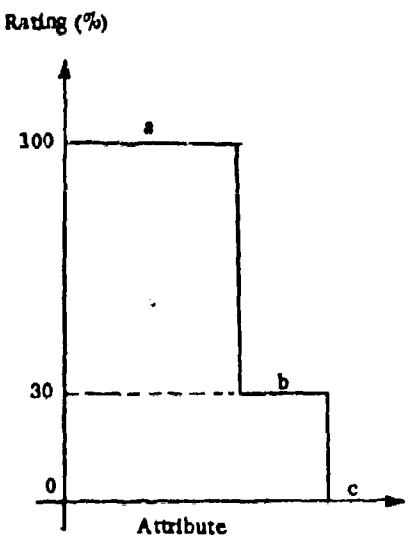
$Z_{C/T}$ / $ZB_{T/D}$, HTC_b } Attribute
$R_{C/T}$, $RB_{T/D}$ } Ratings

If WMS black water T/D subsystem employs a holding tank.

NOTE: $Z_{C/T}$ and $ZB_{T/D}$ are not vessel dependent

HTC_b is vessel dependent

Definitions and corresponding ratings for $Z_{C/T}$ and $ZB_{T/D}$ (if a holding tank is not employed or if a holding tank is employed and HTC_b = 100%)



(a) WMS black water subsystem will handle additional personnel with little or no degradation in performance.

(b) WMS black water subsystem will handle additional personnel with moderately degraded, but still barely acceptable, performance.

(c) WMS black water subsystem will not handle additional personnel.

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E II - PERFORMANCE

332 Ability of gray water portion of WMS to handle additional personnel (on a long-term basis)*

Effectiveness Rating Function

Data given in the form:

$ZG_{T/D}$ - If WMS gray water T/D subsystem does not employ a holding tank

$ZG_{T/D}$, HTC_g - If WMS gray water subsystem employs a holding tank

HTC_g - % of required gray water (or sludge) holding tank capacity provided by installation.

NOTE: 1. $ZG_{T/D}$ is not vessel dependent

2. HTC_g is vessel dependent

(Continued)

* Resulting in a long term increase in average black water stream hydraulic loading. The ability of a WMS which employs a gray water (or sludge) holding tank to handle additional personnel may be determined by the size of that tank; optimum sizing cannot always be provided on the vessel.

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Con Anal.
✓	✓	

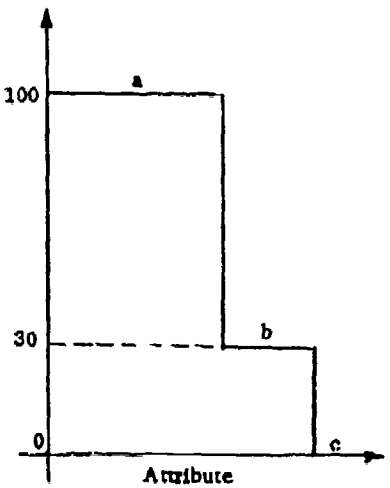
Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	.19	0	.1	0	b, 0	0	.55	0	.100	30	.0	0
2	.18	0	.1	0	b, 0	0	.64	0	.100	30	N	A
3	.13	0	N	A	b, 12	0	.64	0	.100	30	N	A
4	.17	0	N	A	b, 22	0	.64	0	.100	30	N	A
5	N	A	N	A	b, 100	30	.100	30	.100	30	N	A
6	N	A	N	A	b, 100	30	.100	30	.100	30	N	A
7	.17	0	N	A	b, 29	0	.64	0	.100	30	N	A
8	N	A	N	A	a	100		100		100	N	A
9	.21	0	.1	0	b, 13	0	.64	0	.100	30	.20	0
10	.21	0	.1	0	b, 35	0	.64	0	.100	30	N	A
11	.17	0	N	A	b, 35	0	.64	0	.100	30	.20	0
12	N	A	N	A	b, 100	30	.100	30	.100	30	N	A
13	N	A	N	A	a	100		100		100	N	A
14	.30	0	.1	0	b, 13	0	.64	0	.100	30	.20	0
15	.33	0	.3	0	b, 35	0	.64	0	.100	30	N	A
16	.17	0	.1	0	b, 35	0	.64	0	.100	30	.20	0
17	N	A	N	A	b, 100	30	.100	30	.100	30	N	A
18	N	A	N	A	a	100		100		100	N	A

Attribute Data → ← Rating

N/A - Not a viable system/vessel combination

Definition and corresponding ratings for $ZG_{T/D}$ (If a holding tank is not employed or if a holding tank is employed and HTC_g = 100%. If a holding tank is employed and HTC_g is less than 100%, (c) applies).



(a) WMS gray water subsystem will handle additional personnel with little or no degradation in performance.

(b) WMS gray water subsystem will handle additional personnel with moderately degraded, but still barely acceptable, performance.

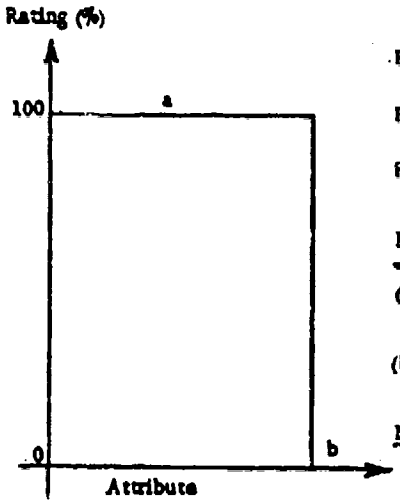
(c) WMS gray water subsystem will not handle additional personnel.

M/E ___ ii - PERFORMANCE

41	Ability of black water handling portion of WMS to operate for sustained time periods

Effectiveness Rating Function

$R_{WMS} = \text{Min}\,(R_{C/T}, RB_{T/D})$



R_{WMS} - Rating for WMS

$R_{C/T}$ - Rating for (black water) C/T subsystem

$RB_{T/D}$ - Rating for black water T/D subsystem

Data given in the form (not vessel dependent):

$Z_{C/T}, ZB_{T/D}$ } Attribute

$R_{C/T}, RB_{T/D}$ } Ratings

Definitions of $Z_{C/T}$ and $ZB_{T/D}$

(a) WMS black water subsystem can operate for an indefinite period of time, if no components fail.

(b) WMS black water subsystem can operate for only a limited period of time, even if no components fail.

NOTE: (a) Applies to WMS black water T/D subsystems with an incinerator.

(b) Applies to WMS black water T/D subsystems without an incinerator.

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cox Anal.
✓		

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1					a, b	0						
2					a, b	0					N	A
3			N	A	a, a	100					N	A
4			N	A	a, b	0					N	A
5	N	A	N	A	a, b	0					N	A
6	N	A	N	A	a, b	0					N	A
7			N	A	a, a	100					N	A
8	N	A	N	A	a, a	100					N	A
9					a, b	0						
10					a, a	100					N	A
11			N	A	a, b	0						
12	N	A	N	A	a, b	0					N	A
13	N	A	N	A	a, a	100					N	A
14					a, b	0						
15					a, a	100					N	A
16					a, b	0						
17	N	A	N	A	a, b	0					N	A
18	N	A	N	A	a, a	100					N	A

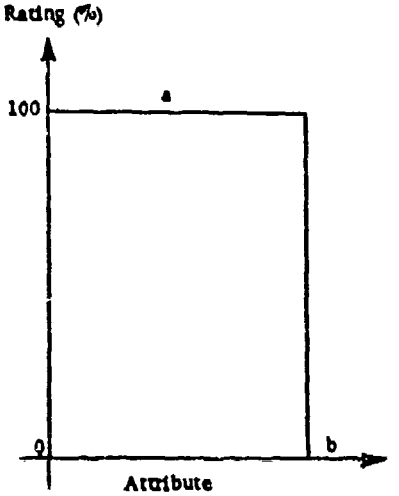
Attribute Data — Rating

N/A - Not a viable system/vessel combination

M/E II - PERFORMANCE

42	Ability of gray water handling portion of WMS to operate for sustained time periods

Effectiveness Rating Function



(a) WMS gray water subsystem can operate for indefinite period of time, if no components fail.

(b) WMS gray water subsystem can operate for only limited period of time, even if no components fail.

NOTES: (1)
a. Applies to WMS gray water T/D subsystems with an incinerator.
b. Applies to WMS gray water T/D subsystems without an incinerator.

(2) Data not vessel dependent.

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Con Anal.
✓		

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1					b	0						
2					b	0					N	A
3			N	A	b	0					N	A
4			N	A	b	0					N	A
5	N	A	N	A	b	0					N	A
6	N	A	N	A	b	0					N	A
7			N	A	b	0					N	A
8	N	A	N	A	a	100					N	A
9					b	0						
10					b	0					N	A
11			N	A	b	0						
12	N	A	N	A	b	0					N	A
13	N	A	N	A	a	100					N	A
14					b	0						
15					b	0					N	A
16					b	0						
17	N	A	N	A	b	0					N	A
18	N	A	N	A	a	100					N	A

Attribute Data ↑ ↑ Rating

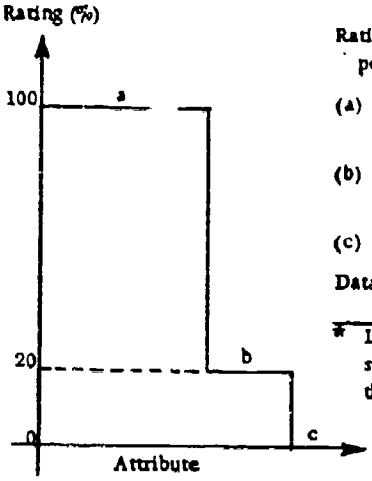
N/A - Not a viable system/vessel combination

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E ____ II - PERFORMANCE

S1 | Ability of WMS to handle ground garbage in black water stream *

Effectiveness Rating Function



Rating for WMS is based on rating for black water T/D subsystems portion which handles the ground garbage (e.g., incinerator or holding tank).

(a) WMS subsystem will handle ground garbage in black water stream on on a long-term basis.

(b) WMS subsystem will handle ground garbage in black water stream on at least at short-term basis.

(c) WMS subsystem will not handle ground garbage in black water stream.

Data is not vessel dependent.

* In some WMS configurations ground garbage bypasses the (sewage) C/T subsystem and instead is routed by a separate line directly into the T/D subsystem (e.g., to holding tank or incinerator).

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Com Anal.
✓		

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1					a	100						
2					a	100					N	A
3			N	A	a	100					N	A
4			N	A	a	100					N	A
5	N	A	N	A	a	100					N	A
6	N	A	N	A	a	100					N	A
7			N	A	b	20					N	A
8	N	A	N	A	b	20					N	A
9					a	100						
10					b	20					N	A
11			N	A	b	20						
12	N	A	N	A	a	100					N	A
13	N	A	N	A	b	20					N	A
14					a	100						
15					b	20					N	A
16					b	20						
17	N	A	N	A	a	100					N	A
18	N	A	N	A	b	20					N	A

Attribute Data ↑ ↑ Rating

N/A - Not a viable system/vessel combination

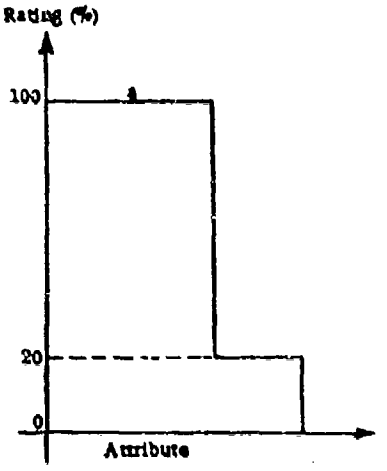
EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/F II - PERFORMANCE

52 Ability of WMS to handle foreign materials/objects * in black water stream

Effectiveness Rating Function

$$R_{WMS} = \text{Min}\,(R_{C/T}, RB_{T/D})$$



R_{WMS} - Rating for WMS

$R_{C/T}$ - Rating for (black water) C/T subsystem

$RB_{T/D}$ - Rating for black water T/D subsystem

(Continued)

* Examples:

- Long, narrow objects (pens, pencils, toothpicks, etc.).
- Small hard objects (nut shells; pull tab from flip top can, bottle caps, paper clips, coins, nuts/bolts/screws/nails, cuff links, etc.).
- Large soft objects (paper towels, newspaper page, stiff and shiny magazine page, strings from a floor mop, rag, tampons, and sanitary napkins, etc.).

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
✓		

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1					a, a	100						
2					a, b	20					N	A
3			N	A	a, b	20					N	A
4			N	A	a, a	100					N	A
5	N	A	N	A	a, a	100					N	A
6	N	A	N	A	a, a	100					N	A
7			N	A	a, a	100					N	A
8	N	A	N	A	a, a	100					N	A
9					b, a	20						
10					b, a	20					N	A
11			N	A	b, c	0						
12	N	A	N	A	b, a	20					N	A
13	N	A	N	A	b, a	20					N	A
14					b, a	20						
15					b, a	20					N	A
16					b, c	0						
17	N	A	N	A	b, a	20					N	A
18	N	A	N	A	b, a	20					N	A

Attribute Data ↑ ↑ Rating

N/A - Not a viable system/vessel combination

Data given in the form (not vessel dependent):

$Z_{C/T}$, $ZB_{T/D}$ } Attribute

$R_{C/T}$, $RB_{T/D}$ } Ratings

Definitions of $Z_{C/T}$ and $ZB_{T/D}$

(a) WMS subsystem will handle foreign materials/objects in black water stream on a long-term basis.

(b) WMS subsystem will handle foreign materials/objects in black water stream on at least a short-term basis.

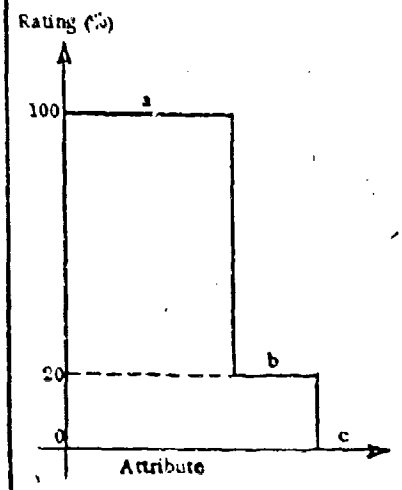
(c) WMS subsystem will not handle foreign materials/objects in black water stream.

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E II - PERFORMANCE

53	Ability of WMS to handle detergents/surfactants in black water stream

Effectiveness Rating Function $R_{WMS} = \text{Min}\,(R_{C/T}, RB_{T/D})$



R_{WMS} - Rating for WMS

$R_{C/T}$ - Rating for (black water) C/T subsystem

$RB_{T/D}$ - Rating for black water T/D subsystem

Data given in the form (not vessel dependent):

$Z_{C/T}, ZB_{T/D}$ } Attribute

$R_{C/T}, RB_{T/D}$ } Ratings

Definitions of $Z_{C/T}$ and $ZB_{T/D}$

(a) WMS subsystem will handle detergents/surfactants in black water stream on a long-term basis.

(b) WMS subsystem will handle detergents/surfactants in black water stream on at least a short-term basis.

(c) WMS subsystem will not handle detergents/surfactants in black water stream.

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
✓		

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1					a, a	100						
2					c, c	0					N	A
3			N	A	c, c	0					N	A
4			N	A	a, a	100					N	A
5	N	A	N	A	a, a	100					N	A
6	N	A	N	A	a, a	100					N	A
7			N	A	a, a	100					N	A
8	N	A	N	A	a, a	100					N	A
9					a, a	100						
10					a, a	100					N	A
11			N	A	a, b	20						
12	N	A	N	A	a, a	100					N	A
13	N	A	N	A	a, a	100					N	A
14					a, a	100						
15					a, a	100					N	A
16					a, b	20						
17	N	A	N	A	a, a	100					N	A
18	N	A	N	A	a, a	100					N	A

Attribute Data ↑ ↓ Rating

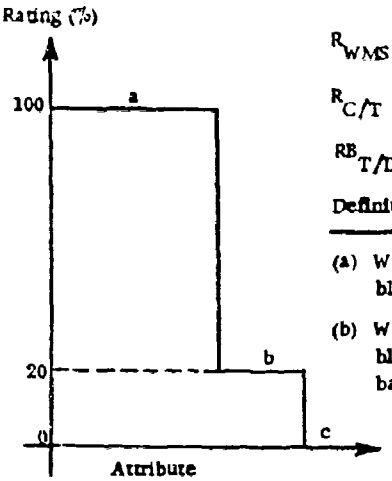
N/A - Not a viable system/vessel combination

M/E II - PERFORMANCE

54 Ability of WMS to handle toxic materials in black water stream

Effectiveness Rating Function

$R_{WMS} = \text{Min}\ (R_{C/T}, RB_{T/D})$



R_{WMS} = Rating for WMS

$R_{C/T}$ = Rating for (black water) C/T subsystem

$RB_{T/D}$ = Rating for black water T/D subsystem

Data given in the form (not vessel dependent):

$\left.\begin{matrix} Z_{C/T} \\ \updownarrow \\ R_{C/T} \end{matrix}\right.$, $\left.\begin{matrix} ZB_{T/D} \\ \updownarrow \\ RB_{T/D} \end{matrix}\right\}$ Attribute / Ratings

Definitions of $Z_{C/T}$ and $ZB_{T/D}$

(a) WMS subsystem will handle toxic materials in black water stream on a long-term basis.

(b) WMS subsystem will handle toxic materials in black water stream on at least a short-term basis.

(c) WMS subsystem will not handle toxic materials in black water stream.

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
✓		

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1					a, a	100						
2					a, a	100					N	A
3			N	A	a, a	100					N	A
4			N	A	a, a	100					N	A
5	N	A	N	A	a, a	100					N	A
6	N	A	N	A	a, a	100					N	A
7			N	A	a, a	100					N	A
8	N	A	N	A	a, a	100					N	A
9					a, a	100						
10					a, a	100					N	A
11			N	A	a, a	100						
12	N	A	N	A	a, a	100					N	A
13	N	A	N	A	a, a	100					N	A
14					a, a	100						
15					a, a	100					N	A
16					a, a	100						
17	N	A	N	A	a, a	100					N	A
18	N	A	N	A	a, a	100					N	A

Attribute Data ↑ ↑ Rating

N/A - Not a viable system/vessel combination

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

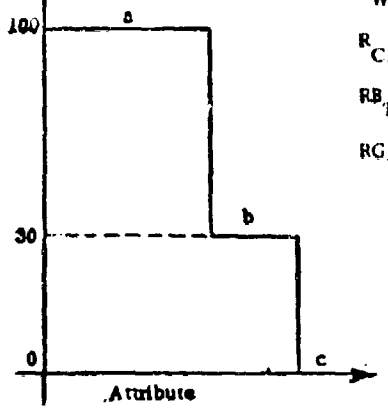
M/E II - PERFORMANCE

61 Ability of WMS secondary emissions to meet applicable standards for the discharge of air pollutants

Effectiveness Rating Function

$$R_{WMS} = \min (R_{C/T}, RB_{T/D}, RG_{T/D})$$

Rating (%)



R_{WMS} - Rating for WMS

$R_{C/T}$ - Rating for (black water) C/T subsystem

$RB_{T/D}$ - Rating for black water T/D subsystem

$RG_{T/D}$ - Rating for gray water T/D subsystem

Data given in the form (not vessel dependent):

$Z_{C/T}$, $ZG_{T/D}$, $ZG_{T/D}$ } Attribute

$R_{C/T}$, $RB_{T/D}$, $RG_{T/D}$ } Ratings

Definitions of $Z_{C/T}$, $ZB_{C/T}$, $ZG_{T/D}$

(a) No possibility of discharge of significant air pollutants from WMS subsystem.

(b) WMS subsystem will meet standards under normal operating conditions and is likely to continue to meet them under unusual operating conditions.

(c) WMS subsystem will meet standards under normal operating conditions and there is a strong possibility of non-conformance to standards under unusual operating conditions.

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
✓		

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1					a, a, a	100						
2					a, a, a	100					N	A
3			N	A	a, b, a	30					N	A
4			N	A	a, a, a	100					N	A
5	N	A	N	A	a, a, a	100					N	A
6	N	A	N	A	a, a, a	100					N	A
7			N	A	a, b, a	30					N	A
8	N	A	N	A	a, b, b	30					N	A
9					a, a, a	100						
10					a, b, a	30					N	A
11			N	A	a, a, a	100						
12	N	A	N	A	a, a, a	100					N	A
13	N	A	N	A	a, b, b	30					N	A
14					a, a, a	100						
15					a, b, a	30					N	A
16					a, a, a	100						
17	N	A	N	A	a, a, a	100					N	A
18	N	A	N	A	a, b, b	30					N	A

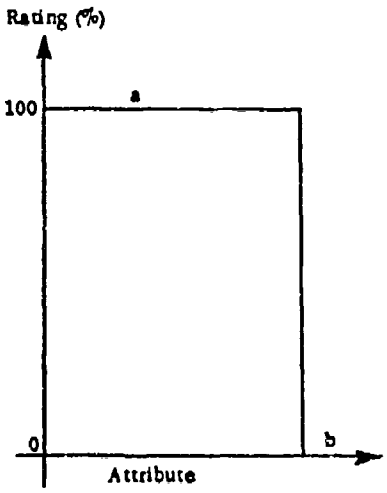
Attribute Data ↑ ↑ Rating

N/A - Not a viable system/vessel combination

62 WMS potential for producing oil contaminated residues at sea

Effectiveness Rating Function

$R_{WMS} = \text{Min}\ (R_{C/T}, RB_{T/D}, RG_{T/D})$



R_{WMS} - Rating for WMS

$R_{C/T}$ - Rating for (black water) C/T subsystem

$RB_{T/D}$ - Rating for black water T/D subsystem

$RG_{T/D}$ - Rating for gray water T/D subsystem

Data given in the form (not vessel dependent):

$Z_{C/T}, ZB_{T/D}, ZG_{T/D}$ } Attribute

$R_{C/T}, RB_{T/D}, RG_{T/D}$ } Ratings

Definitions of $Z_{C/T}, ZB_{T/D}, ZG_{T/D}$

(a) WMS subsystem has no potential for producing oil-contaminated residues at sea.

(b) WMS has a potential for producing oil-contaminated residues at sea.

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
✓		

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1					a, b, b	0						
2					b, b, b	0					N	A
3			N	A	b, b, b	0					N	A
4			N	A	a, b, b	0					N	A
5	N	A	N	A	a, b, b	0					N	A
6	N	A	N	A	a, b, b	0					N	A
7			N	A	a, b, b	0					N	A
8	N	A	N	A	a, b, b	0					N	A
9					a, b, b	0						
10					a, a, b	0					N	A
11			N	A	a, a, b	0						
12	N	A	N	A	a, b, b	0					N	A
13	N	A	N	A	a, a, b	0					N	A
14					a, b, b	0						
15					a, a, b	0					N	A
16					a, a, b	0						
17	N	A	N	A	a, b, b	0					N	A
18	N	A	N	A	a, a, b	0					N	A

Attribute Data ↑ ↑ Rating

N/A - Not a viable system/vessel combination

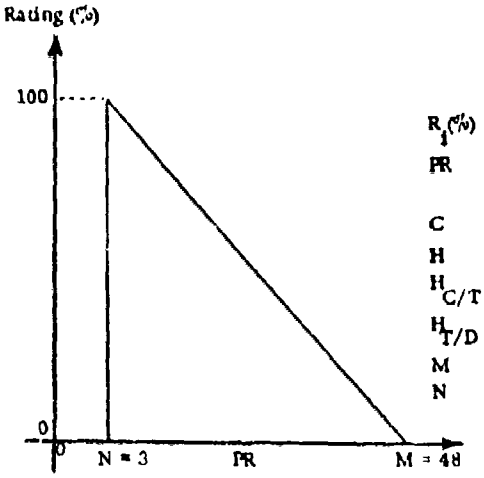
EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E II - PERFORMANCE

71	Performance risk for black water handling portion of WMS

Effectiveness Rating Function

$$R_i(\%) = 100 - \frac{100}{45}(PR - 3) \qquad 3 \le PR \le 48$$



$PR = C \times H$

$H = 2H_{C/T} + H_{T/D}$

$R_i(\%)$ - Rating (%) of ith viable candidate WMS (independent of vessel)

PR - Performance risk factor of ith viable candidate WMS (independent of vessel) due to configuration type and test history

C - WMS configuration index

H - History index for WMS

$H_{C/T}$ - History index for WMS (black water) C/T subsystem

$H_{T/D}$ - History index for WMS black water T/D subsystem

M - Maximum possible value of PR = 4(2×4+4) = 48

N - Minimum value of PR = 1(2x1+1) = 3

(Continued)

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
✓		

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1					a/a, a	100						
2					b/a, a	93					N	A
3			N	A	a/a, b	93					N	A
4			N	A	b/a, b	80					N	A
5	N	A	N	A	b/a, b	80					N	A
6	N	A	N	A	a/a, a	100					N	A
7			N	A	a/a, b	93					N	A
8	N	A	N	A	a/a, b	93					N	A
9					b/a, a	93						
10					a/a, b	93					N	A
11			N	A	c/a, a	80						
12	N	A	N	A	b/a, a	93					N	A
13	N	A	N	A	c/a, b	53					N	A
14					b/a, a	93						
15					c/a, b	53					N	A
16					a/a, a	100						
17	N	A	N	A	b/a, a	93					N	A
18	N	A	N	A	c/a, b	53					N	A

Attribute Data → ← Rating

N/A - Not a viable system/vessel combination

Definition and values for C

(a) WMS black water handling configuration is not a hybrid (C = 1)

(b) WMS black water handling configuration is a hybrid but no serious performance or interface problems are anticipated (C = 2)

(c) WMS black water configuration is a hybrid and there are uncertainities about its performance and/or the success of integrating the hybrid (i.e., providing the necessary interfaces between equipments/subsystems of different MSDs) (C = 4)

C	Applies to WMS No.
a	1, 3*, 6, 7, 8, 10*, 16*
b	2, 4, 5, 9, 12, 14, 17
c	11*, 13*+, 15*+, 18*+

* Ability to handle garbage slurry uncertain.
\+ Performance and integration uncertain.

Definition and values for $H_{C/T}$ and $H_{T/D}$

(a) WMS black water subsystem has a history of fair or better test results ($H_{C/T}$ or $H_{T/D}$ = 1).

(b) WMS black water subsystem has a history of poor test results ($H_{C/T}$ or $H_{T/D}$ = 4).

(c) No test results are available for the MSD black water subsystem ($H_{C/T}$ or $H_{T/D}$ = 3).

Data given in the form (not vessel dependent):

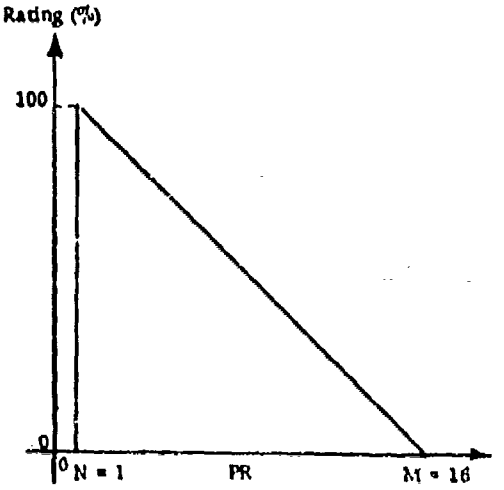
$C/H_{C/T}$, $H_{T/D}$

M/E II - PERFORMANCE

72	Performance risk for gray water handling portion of WMS

Effectiveness Rating Function

$$R_i(\%) = 100 - \frac{100}{15}(PR - 1) \qquad 1 \le PR \le 16$$



PR = C x H

R_i (%) = Rating (%) of ith viable candidate WMS (independent of vessel)

PR = Performance risk factor of ith candidate WMS (independent of vessel) due to configuration type and test history

C = WMS configuration type index

H = History index for WMS gray water Treatment/Disposal subsystem

M = Maximum possible value of PR = 4 (4) = 16

N = Minimum value of PR = 1 (1) = 1

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Con Anal.
✓		

(Continued)

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1					a / a	100						
2					a / a	100					N	A
3			N	A	a / a	100					N	A
4			N	A	a / a	100					N	A
5	N	A	N	A	b / b	53					N	A
6	N	A	N	A	b / b	53					N	A
7			N	A	a / a	100					N	A
8	N	A	N	A	a / b	80					N	A
9					a / a	100						
10					a / a	100					N	A
11			N	A	a / a	100						
12	N	A	N	A	b / b	53					N	A
13	N	A	N	A	c / b	0					N	A
14					a / a	100						
15					a / a	100					N	A
16					a / a	100						
17	N	A	N	A	b / b	53					N	A
18	N	A	N	A	c / b	0					N	A

Attribute Data — Rating

N/A = Not a viable system/vessel combination

Definition and values for C

(a) WMS gray water handling configuration is not a hybrid (C = 1)

(b) WMS gray water handling configuration is a hybrid but no serious performance or interface problems are anticipated (C = 2)

(c) WMS gray water handling configuration is a hybrid and there are uncertainities about its performance and/or the success of integrating the hybrid (i.e., providing the necessary interfaces between equipments/ subsystems of different MSDs) (C = 4)

C	Applies to WMS No.
a	1, 2, 3, 4, 7, 8, 9, 10, 11, 14, 15, 16
b	5, 6, 12, 17
c	13*, 18*

* Black water stream fed to sludge incinerator.

Definition and values for H

(a) WMS gray water subsystem has a history of fair or better test results (H = 1)

(b) WMS gray water subsystem has a history of poor test results (H = 4)

(c) No test results are available for the WMS gray water subsystem (H = 3)

Data given in the form (not vessel dependent):

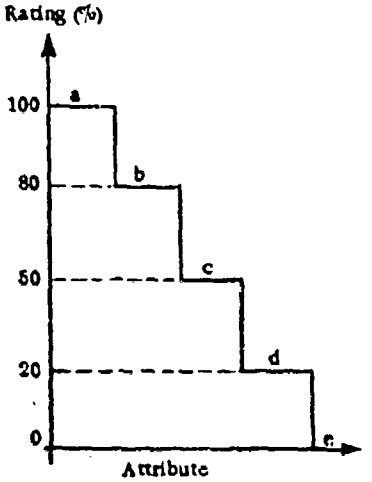
C/H

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E III - OPERABILITY

11	Degree of automation for WMS operation

Effectiveness Rating Function $R_{WMS} = \text{Min}\,(R_{C/T}, RB_{T/D}, RG_{T/D})$



R_{WMS} - Rating for WMS

$R_{C/T}$ - Rating for (black water) C/T subsystem

$RB_{T/D}$ - Rating for black water T/D subsystem

$RG_{T/D}$ - Rating for gray water T/D subsystem

Data given in the form (not vessel dependent):

$ZC_{C/T}, ZB_{T/D}, ZG_{T/D}$ } Attribute

$R_{C/T}, RB_{T/D}, RG_{T/D}$ } Ratings

(Continued)

Source of Data		
NSD Anal.	WMS Install. Anal.	WMS Cost Anal.
√		

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1					a,b,b	80						
2					a,c,b	50					N	A
3			N	A	a,c,b	50					N	A
4			N	A	a,a,b	80					N	A
5	N	A	N	A	a,a,a	100					N	A
6	N	A	N	A	a,b,a	80					N	A
7			N	A	a,b,b	80					N	A
8	N	A	N	A	a,b,b	80					N	A
9					b,b,b	80						
10					b,b,b	80					N	A
11			N	A	b,b,b	80						
12	N	A	N	A	b,b,a	80					N	A
13	N	A	N	A	b,b,b	80					N	A
14					a,b,b	80						
15					a,b,b	80					N	A
16					a,b,b	80						
17	N	A	N	A	a,b,a	80					N	A
18	N	A	N	A	a,b,b	80					N	A

Attribute Data — Rating

N/A - Not a viable system/vessel combination

Definition of $Z_{C/T}$, $ZB_{T/D}$, $ZG_{T/D}$

(a) WMS subsystem is almost fully automatic.

(b) WMS subsystem is semi-automatic: requires infrequent operator attention.

(c) WMS subsystem is semi-automatic: requires moderate degree of operator attention.

(d) WMS subsystem is semi-automatic: requires frequent operator attention.

(e) WMS subsystem is operated manually.

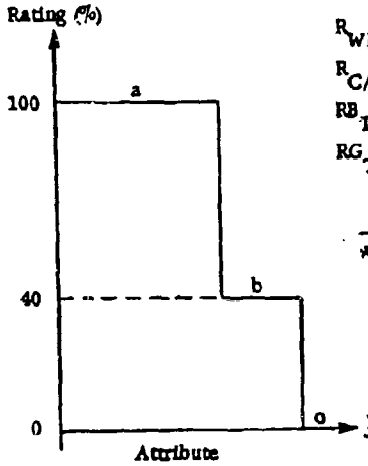
EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E ____ III - OPERABILITY

12 Ease of disposal of WMS residue(s)*

Effectiveness Rating Function

$R_{WMS} = \text{Min}\ (R_{C/T}, RB_{T/D}, RG_{T/D})$



R_{WMS} - Rating for WMS

$R_{C/T}$ - Rating for (black water) C/T subsystem

$RB_{T/D}$ - Rating for black water T/D subsystem

$RG_{T/D}$ - Rating for gray water T/D subsystem

(Continued)

* Residue is any by-product of normal WMS operation, disposal of which is a regular operating task. Examples are ash produced by an incinerator, seal water used by JERED vacuum pumps, evaporator residue, sludge or wastewater held in a tank, etc.

NOTE: Length of time required for disposal is the main factor in determining the rating; other factors are ease of access to area of WMS containing the residue, amount of residue to be disposed of, and ease of storing residue on board or taking it off vessel, as appropriate.

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
✓		

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1					a, b, b	40						
2					a, b, b	40					N	A
3			N	A	a, b, b	40					N	A
4			N	A	a, b, b	40					N	A
5	N	A	N	A	a, b, b	40					N	A
6	N	A	N	A	a, b, b	40					N	A
7			N	A	a, b, b	40					N	A
8	N	A	N	A	a, b, b	40					N	A
9					b, b, b	40						
10					b, b, b	40					N	A
11			N	A	b, b, b	40						
12	N	A	N	A	b, b, b	40					N	A
13	N	A	N	A	b, b, b	40					N	A
14					a, b, b	40						
15					a, b, b	40					N	A
16					a, b, b	40						
17	N	A	N	A	a, b, b	40					N	A
18	N	A	N	A	a, b, b	40					N	A

Attribute Data ↑ ↑ Rating

N/A - Not a viable system/vessel combination

III - 12

Data given in the form (not vessel dependent):

$$\left.\begin{matrix} Z_{C/T} \\ \updownarrow \\ R_{C/T} \end{matrix}\right. , \left.\begin{matrix} ZB_{T/D} \\ \updownarrow \\ RB_{T/D} \end{matrix}\right. , \left.\begin{matrix} ZG_{T/D} \\ \downarrow \\ RG_{T/D} \end{matrix}\right.$$

Attribute

Ratings

Definitions of $Z_{C/T}$, $ZB_{T/D}$, $ZG_{T/D}$

(a) WMS subsystem has no residues, or disposal of residue is very convenient.

(b) Disposal of residue from WMS subsystem is moderately convenient.

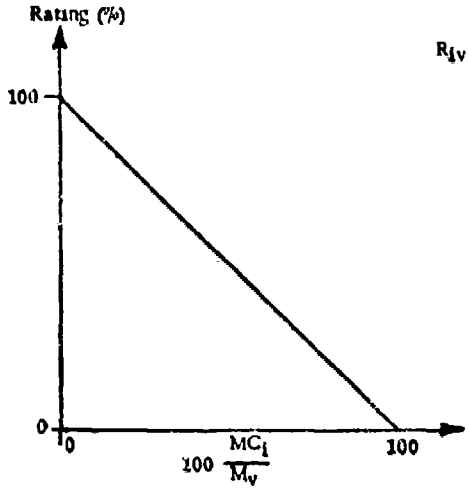
(c) Disposal of residue from WMS subsystem in inconvenient.

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E III - OPERABILITY

13	Ease of WMS mode changeovers*(relative)

Effectiveness Rating Function



$$R_{iv}(\%) = 100 - 100\frac{MC_i}{M_v} \qquad 0 \leq \frac{MC_i}{M_v} \leq 1.0$$

$R_{iv}(\%)$ - Rating (%) of ith viable candidate WMS on vessel v

MC_i - Annual man-hours** for mode changeovers for i^{th} viable candidate WMS on vessel v based on projected WMS utilization

M_v - Maximum value of MC_i for all viable WMS candiate for a given vessel

* Primary to overboard discharge mode cycle/pierside to primary mode cycle.

** Based on the number of annual mode changeovers for vessel.

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
		✓

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	13	63	8	62	40	61	11	59	30	61	23	62
2	27	23	17	19	87	15	24	11	66	13	N	A
3	27	23	N	A	87	15	24	11	66	13	N	A
4	27	23	N	A	87	15	24	11	66	13	N	A
5	N	A	N	A	87	15	24	11	66	13	N	A
6	N	A	N	A	87	15	24	11	66	13	N	A
7	27	23	N	A	87	15	24	11	66	13	N	A
8	N	A	N	A	87	15	24	11	66	13	N	A
9	25	29	16	24	79	23	11	59	59	22	23	62
10	25	29	16	24	79	23	11	59	59	22	N	A
11	25	29	N	A	79	23	11	59	59	22	23	62
12	N	A	N	A	79	23	11	59	59	22	N	A
13	N	A	N	A	79	23	11	59	59	22	N	A
14	(35)	0	(21)	0	(102)	0	(27)	0	(76)	0	(61)	0
15	35	0	21	0	102	0	27	0	76	0	N	A
16	35	0	21	0	102	0	27	0	76	0	61	0
17	N	A	N	A	102	0	27	0	76	0	N	A
18	N	A	N	A	102	0	27	0	76	0	N	A

Attribute Data ↑ ↑ Rating

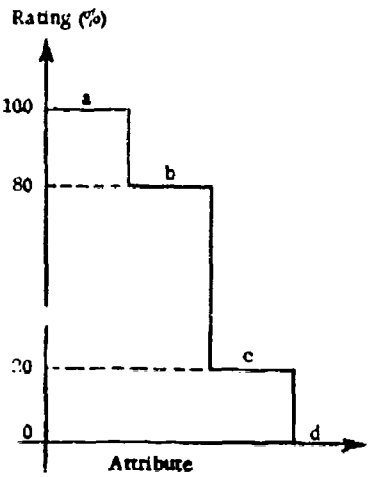
N/A - Not a viable system/vessel combination

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E _____ III - OPERABILITY

14	Likelihood of violating effluent standards because of procedural errors* in WMS operation

Effectiveness Rating Function $R_{WMS} = \text{Min}\,(R_{C/T}, RB_{T/D}, RG_{T/D})$



R_{WMS} = Rating for WMS

$R_{C/T}$ = Rating for (black water) C/T subsystem

$RB_{T/D}$ = Rating for black water T/D subsystem

$RG_{T/D}$ = Rating for gray water T/D subsystem

Data given in the form (not vessel dependent):

$$\left.\begin{matrix} Z_{C/T} \\ \updownarrow \\ R_{C/T} \end{matrix}\right\} \text{Attribute}, \quad \left.\begin{matrix} ZB_{T/D} \\ \updownarrow \\ RB_{T/D} \end{matrix}\right\} \text{Attribute}, \quad \left.\begin{matrix} ZG_{T/D} \\ \updownarrow \\ RG_{T/D} \end{matrix}\right\} \text{Attribute}$$

Ratings

* By dumping overboard effuent which doesn't meet standards, flush oil, evaporator residue, air pollutants from incinerator, etc.

(Continued)

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
✓		

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1					a,b,b	80						
2					a,c,b	20					N	A
3			N	A	a,c,b	20					N	A
4			N	A	a,c,b	20					N	A
5	N	A	N	A	a,c,c	20					N	A
6	N	A	N	A	a,b,c	20					N	A
7			N	A	a,d,b	0					N	A
8	N	A	N	A	a,d,d	0					N	A
9					b,b,b	80						
10					b,b,b	80					N	A
11			N	A	b,b,b	80						
12	N	A	N	A	b,b,c	20					N	A
13	N	A	N	A	b,b,d	0					N	A
14					a,b,b	80						
15					a,b,b	80					N	A
16					a,b,b	80						
17	N	A	N	A	a,b,c	20					N	A
18	N	A	N	A	a,b,d	0					N	A

Attribute Data ↑ ↑ Rating

N/A - Not a viable system/vessel combination

Definitions of $Z_{C/T}$, $ZB_{T/D}$, $ZG_{T/D}$

(a) There is virtually no chance of violating effluent standards because of procedural errors.

(b) There is a low likelihood of violating effluent standards because of procedural error in WMS operation.

(c) There is fair to moderate chance of violating effluent standards because of procedural error in WMS operation.

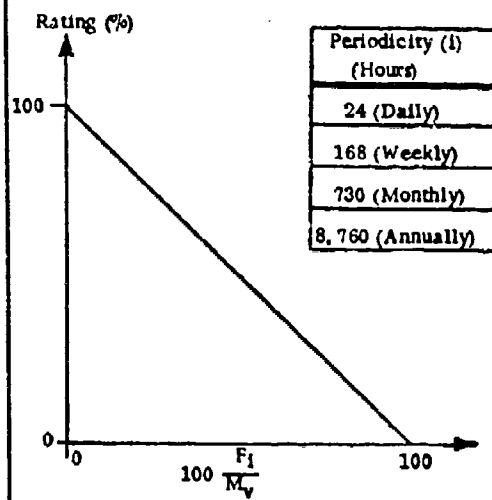
(d) There is a high likelihood of violating standards because of procedural error in WMS operation.

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E III - OPERABILITY

21	Frequency of WMS operator attention required (relative)

Effectiveness Rating Function



Periodicity (j) (Hours)	w_j
24 (Daily)	365
168 (Weekly)	52
730 (Monthly)	12
8,760 (Annually)	1

$$F_i = \sum_{j} w_j f_j$$

$$R_{iv}(\%) = 100 - 100 \frac{F_i}{M_v} \qquad 0 \le \frac{F_i}{M_v} \le 1.0$$

j - All operator actions for i^{th} viable candidate WMS on vessel v

$R_{iv}(\%)$ - Rating (%) of ith viable candidate WMS on vessel v

F_i - Annual number of WMS operator actions

f_j - Number of WMS operator actions at j^{th} periodicity

w_j - Penalty of weight for j^{th} periodicity of operator actions

M_v - Maximum value of F_j for all viable WMS candidates for a given vessel v

Source of ...		
MSD Anal.	WMS Install. Anal.	...MS Cost Anal.
		✓

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	1460	91	730	91	365	95	730	83	730	80	730	53
2	2963	82	1231	86	866	87	1231	71	1231	67	N	A
3	2361	86	N	A	942	86	918	79	866	77	N	A
4	4716	71	N	A	2358	65	2358	44	2358	36	N	A
5	N	A	N	A	3621	46	1993	53	1993	46	N	A
6	N	A	N	A	3621	46	1993	53	2358	36	N	A
7	4370	73	N	A	2133	68	2133	50	2133	42	N	A
8	N	A	N	A	3536	47	1768	58	1768	52	N	A
9	16,177	2	8095	6	4132	38	2607	38	2659	28	(1564)	0
10	16,305	1	(8576)	0	3831	42	2422	43	2526	32	N	A
11	(16,455)	0	N	A	4001	40	2371	44	2411	35	1315	16
12	N	A	N	A	(6658)	0	(4235)	0	2723	26	N	A
13	N	A	N	A	4788	28	3685	13	(3697)	0	N	A
14	1460	91	730	91	730	89	730	83	730	80	730	53
15	1524	91	1159	86	1159	83	505	88	505	86	N	A
16	1738	89	773	91	633	90	485	89	481	87	481	69
17	N	A	N	A	3986	40	2358	44	2358	36	N	A
18	N	A	N	A	2048	69	1768	58	1026	72	N	A

Attribute Data ↑ ↑ Rating

N/A - Not a viable system/vessel combination

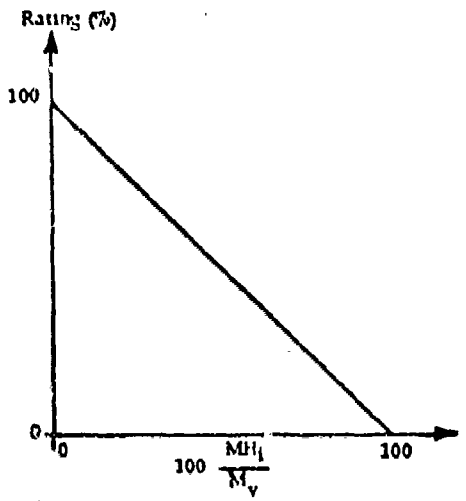
EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E ____ III - OPERABILITY

22	Number of man-hours of operator attention for WMS (relative)

Effectiveness Rating Function

$$R_{iv}(\%) = 100 - 100\frac{MH_i}{M_v} \qquad 0 \le \frac{MH_i}{M_v} \le 1.0$$



$R_{iv}(\%)$ - Rating (%) of ith viable candidate WMS on vessel v

MH_i - Annual operator man-hours required for i^{th} viable candidate WMS on vessel v based on projected WMS utilization.

M_v - Maximum value of MH_i for all viable WMS candidates on a given vessel v.

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
		✓

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	40	91	15	94	49	80	49	65	44	71	24	70
2	237	45	85	65	157	37	123	13	129	16	N	A
3	226	47	N	A	158	37	106	25	134	13	N	A
4	67	84	N	A	113	55	81	43	87	44	N	A
5	N	A	N	A	113	55	62	56	79	49	N	A
6	N	A	N	A	113	55	62	56	87	44	N	A
7	60	86	N	A	108	57	71	50	83	46	N	A
8	N	A	N	A	112	55	52	63	76	51	N	A
9	406	5	237	2	231	7	122	14	150	3	80	0
10	419	2	(241)	0	240	4	112	21	143	7	N	A
11	(428)	0	N	A	233	6	82	42	143	7	80	0
12	N	A	N	A	(249)	0	(142)	0	(154)	0	N	A
13	N	A	N	A	234	6	113	20	143	7	N	A
14	62	86	28	88	119	52	65	54	90	42	63	21
15	62	86	31	87	128	49	54	62	86	44	N	A
16	84	80	31	87	121	51	55	61	86	44	63	21
17	N	A	N	A	137	45	84	41	97	37	N	A
18	N	A	N	A	122	51	55	61	86	44	N	A

Attribute Data ↑ ↑ Rating

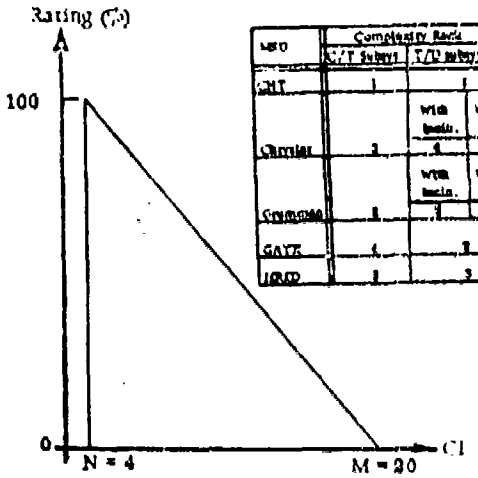
N/A - Not a viable system/vessel combination

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E III - OPERABILITY

23	Skill level requirements for operators of WMS

Effectiveness Rating Function



Mode	Complexity Rank	
	C/T Subsys	T/D subsystem
CHT	1	1
Chemlet	3	With Incin. 4 / With Hold Tank 3
Commode	3	With Incin. 4 / With Hold Tank 3
GATE	4	3
LOOP	3	3

$$R_i(\%) = 100\left(1 - \frac{CI_i}{M}\right) \quad 0 \le \frac{CI_i}{M} \le 1.0$$

$$CI = 2\,CI_{C/T} + CIB_{T/D} + CIG_{T/D}$$

$R_i(\%)$ = Rating (%) of ith viable candidate WMS (independent of vessel)

CI - Complexity index of ith viable WMS candidate (independent of vessel)

$CI_{C/T}$ - Complexity index of WMS (black water) Collection/Transport subsystem based on a complexity ranking.

$CIB_{T/D}$ - Complexity index of WMS black water Treatment/Disposal subsystem based on a complexity ranking.

$CIG_{T/D}$ - Complexity index of WMS gray water Treatment/Disposal subsystem based on a complexity ranking.

M - Maximum value of CI for any WMS (independent vessel) = 2 (5) + 5 + 5 = 20

N = Minimum value of CI = 2(1) + 1 + 1 = 4

Data given in the form (not vessel dependent): $CI_{C/T}$, $CIB_{T/D}$, $CIG_{T/D}$

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
		X

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1					1,1,1							
2					3,3,1						N	A
3			N	A	3,4,1						N	A
4			N	A	2,5,1						N	A
5	N	A	N	A	2,5,5						N	A
6	N	A	N	A	1,1,5						N	A
7			N	A	2,6,1						N	A
8	N	A	N	A	2,5,5						N	A
9					5,1,1							
10					5,3,1						N	A
11			N	A	5,2,1							
12	N	A	N	A	5,1,5						N	A
13	N	A	N	A	5,5,5						N	A
14					4,1,1							
15					4,3,1						N	A
16					4,2,1							
17	N	A	N	A	4,1,5						N	A
18	N	A	N	A	4,5,5						N	A

Attribute Data ↑ ↑ Rating

N/A = Not a viable system/vessel combination

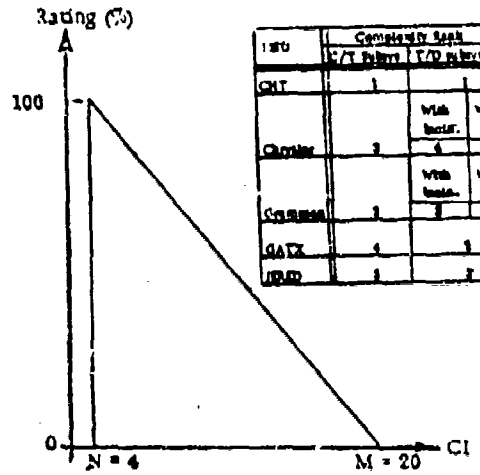
EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E _____ III - OPERABILITY

24	Training requirements for operators of WMS

Effectiveness Rating Function

$$R_I(\%) = 100 - \frac{100}{16}(CI - 4) \quad | \quad 4 \le CI \le 20$$



WMS	Complexity Rank	
	C/T Subsys	T/D Subsystem
GMT	1	1
Chamber	3	With Incin. 4 / With Hold Tank 3
Centrifuge	3	With Incin. 3 / With Hold Tank 2
CATK	4	3
VRCS	3	2

$$CI = 2\,CI_{C/T} + CIB_{T/D} + CIG_{T/D}$$

$R_I(\%)$ = Rating (%) of Ith viable candidate WMS (independent of vessel)

CI - Complexity index of Ith viable WMS candidate (independent of vessel)

$CI_{C/T}$ - Complexity index of WMS (black water) Collection/Transport subsystem based on a complexity ranking.

$CIB_{T/D}$ - Complexity index of WMS black water Treatment/Disposal subsystem based on a complexity ranking.

$CIG_{T/D}$ - Complexity index of WMS gray water Treatment/Disposal subsystem based on a complexity ranking.

M - Maximum value of CI for any WMS (independent vessel) = 2 (5) + 5 + 5 = 20

N - Minimum value of CI = 2(1) + 1 + 1 = 4

Data given in the form (not vessel dependent):

$CI_{C/T}$, $CIB_{T/D}$, $CIG_{T/D}$

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Con Anal.
✓		

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1					1,1,1	100						
2					3,3,1	63					N	A
3			N	A	3,4,1	56					N	A
4			N	A	2,5,1	63					N	A
5	N	A	N	A	2,5,5	38					N	A
6	N	A	N	A	1,1,5	75					N	A
7			N	A	2,5,1	63					N	A
8	N	A	N	A	2,5,5	38					N	A
9					5,1,1	50						
10					5,3,1	38					N	A
11			N	A	5,2,1	44						
12	N	A	N	A	5,1,5	25					N	A
13	N	A	N	A	5,5,5	0					N	A
14					4,1,1	63						
15					4,3,1	50					N	A
16					4,2,1	56						
17	N	A	N	A	4,1,5	38					N	A
18	N	A	N	A	4,5,5	13					N	A

Attribute Data → ← Rating

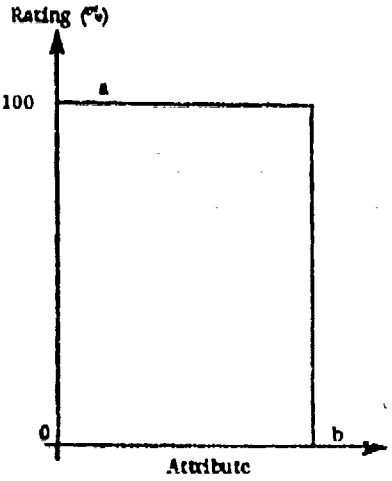
N/A - Not a viable system/vessel combination

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E III - OPERABILITY

25	Effect of WMS operation on vessel work routines/schedules

Effectiveness Rating Function



(a) WMS operation has minimal or no effect on work routines/scheduling.

(b) Effect of WMS operation on work routines/schedules is more than minimal (i.e., is moderate or extensive).

NOTE: By C.G. direction, (a) applies to all WMS considered in this study.

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Con Anal.
✓		

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1					a	100						
2											N	A
3			N	A							N	A
4			N	A							N	A
5	N	A	N	A							N	A
6	N	A	N	A							N	A
7			N	A							N	A
8	N	A	N	A							N	A
9												
10											N	A
11			N	A								
12	N	A	N	A							N	A
13	N	A	N	A							N	A
14												
15											N	A
16												
17	N	A	N	A							N	A
18	N	A	N	A							N	A

Attribute Data → ← Rating

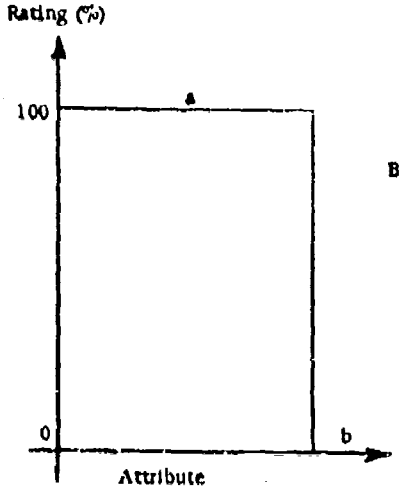
N/A - Not a viable system/vessel combination

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E III - OPERABILITY

26	Additional personnel (billets) requirements for WMS operation

Effectiveness Rating Function



(a) No additional billets are required. WMS operation requires less than 8 hours/day of operator attention.

(b) One or more additional billets are required. WMS operator requires 8 hours/day or more of operator attention.

$$B = \frac{\text{Annual man-hours}^{*} \text{ required for operating 1 viable candidate WMS on vessel v}}{2080}$$

If $B \geq 1$, choose b

If $B < 1$, choose a

* Based on project WMS utilization factor.

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Con Anal. ✓

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	78	100	15	100	49	100	49	100	44	100	25	100
2	237	100	85	100	157	100	123	100	129	100	N	A
3	226	100	N	A	158	100	106	100	134	100	N	A
4	94	100	N	A	113	100	81	100	87	100	N	A
5	N	A	N	A	202	100	62	100	79	100	N	A
6	N	A	N	A	210	100	62	100	87	100	N	A
7	86	100	N	A	108	100	71	100	83	100	N	A
8	N	A	N	A	200	100	52	100	76	100	N	A
9	419	100	237	100	231	100	104	100	150	100	80	100
10	432	100	241	100	240	100	112	100	143	100	N	A
11	426	100	N	A	233	100	82	100	143	100	80	100
12	N	A	N	A	249	100	142	100	154	100	N	A
13	N	A	N	A	234	100	113	100	143	100	N	A
14	62	100	24	100	119	100	65	100	90	100	63	100
15	62	100	31	100	128	100	54	100	86	100	N	A
16	69	100	31	100	121	100	55	100	86	100	63	100
17	N	A	N	A	137	100	84	100	97	100	N	A
18	N	A	N	A	122	100	55	100	86	100	N	A

Attribute Data ↑ ↑ Rating

N/A - Not a viable system/vessel combination

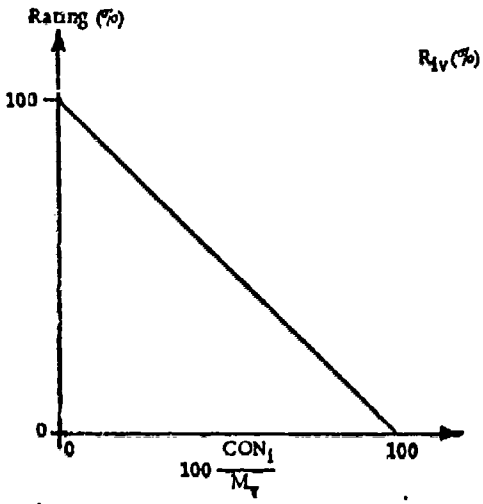
EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E III - OPERABILITY

31	Amount of consumables/expendables required for WMS operation (relative)

Effectiveness Rating Function

$$R_{iv}(\%) = 100 - 100\,\frac{CON_i}{M_v} \qquad 0 \le \frac{CON_i}{M_v} \le 1.0$$



$R_{iv}(\%)$ - Rating (%) of ith viable candidate WMS on vessel v

CON_i - Annual cost ($/Year) of consumables/expendables for i^{th} viable candidate WMS on vessel v based on projected WMS utilization

M_v - Maximum value of CON_i for all viable candidate WMS on vessel v

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal. ✓

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

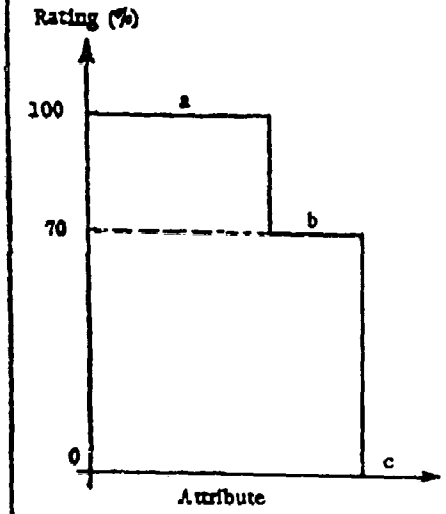
WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	0	100	0	100	0	100	0	100	0	100	0	100
2	2547	0	849	0	849	0	711	0	711	0	N	A
3	2547	0	N	A	849	0	711	0	711	0	N	A
4	18	99	N	A	11	99	25	97	9	99	N	A
5	N	A	N	A	23	97	25	97	9	99	N	A
6	N	A	N	A	23	97	25	97	9	99	N	A
7	18	99	N	A	11	99	25	97	9	99	N	A
8	N	A	N	A	23	97	25	97	9	99	N	A
9	0	100	0	100	0	100	0	100	0	100	0	100
10	0	100	0	100	0	100	0	100	0	100	N	A
11	0	100	N	A	0	100	0	100	0	100	0	100
12	N	A	N	A	23	97	25	97	9	99	N	A
13	N	A	N	A	11	99	25	97	9	99	N	A
14	0	100	0	100	0	100	0	100	0	100	0	100
15	0	100	0	100	0	100	0	100	0	100	N	A
16	0	100	0	100	0	100	0	100	0	100	0	100
17	N	A	N	A	23	97	25	97	9	99	N	A
18	N	A	N	A	11	99	25	97	9	99	N	A

Attribute Data ↑ ↑ Rating

N/A - Not a viable system/vessel combination

32	Availability of specialized or unique consumables/expendables required for WMS operation

Effectiveness Rating Function $R_{WMS} = \text{Min}\,(R_{C/T}, RB_{T/D}, RG_{T/D})$



R_{WMS} - Rating for WMS

$R_{C/T}$ - Rating for (black water) C/T subsystem

$RB_{T/D}$ - Rating for black water T/D subsystem

$RG_{T/D}$ - Rating for gray water T/D subsystem

Data given in the form (not vessel dependent):

$Z_{C/T}$, $ZB_{T/D}$, $ZG_{T/D}$ } Attribute

$R_{C/T}$, $RB_{T/D}$, $RG_{T/D}$ } Ratings

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
✓		

(Continued)

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1					a, a, a	100						
2					a, d, a	0					N	A
3			N	A	a, d, a	0					N	A
4			N	A	a, a, a	100					N	A
5	N	A	N	A	a, a, a	100					N	A
6	N	A	N	A	a, a, a	100					N	A
7			N	A	a, d, a	0					N	A
8	N	A	N	A	a, d, d	0					N	A
9					a, a, a	100						
10					a, d, a	0					N	A
11			N	A	a, a, a	100						
12	N	A	N	A	a, a, a	100					N	A
13	N	A	N	A	a, d, d	0					N	A
14					a, a, a	100						
15					a, d, a	0					N	A
16					a, a, a	100						
17	N	A	N	A	a, a, a	100					N	A
18	N	A	N	A	a, d, d	0					N	A

Attribute Data ↑ ↑ Rating

N/A - Not a viable system/vessel combination

Definitions of $Z_{C/T'}$ $ZB_{T/D'}$ $ZG_{T/D}$

(a) No specialized or unique consumables or expendables required for WMS subsystem operation.

(b) Any specialized or unique consumables or expendables required for WMS subsystem operation are available from ship's inventory.

(c) Any specialized or unique consumables or expendables required for WMS subsystem operation are available from federal stock system.

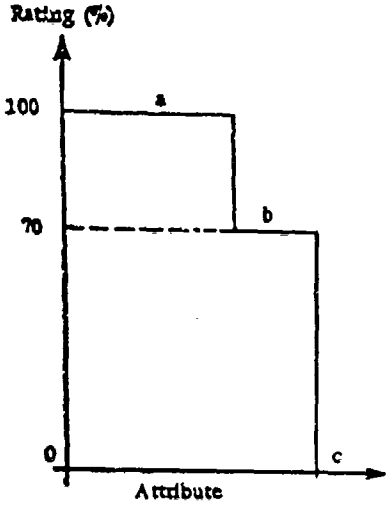
(d) Any specialized or unique consumables or expendables required for WMS subsystem operation are available only from commercial source.

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E ____ III - OPERABILITY ____

33 Operating requirements for special or unique WMS support equipment

Effectiveness Rating Function $R_{WMS} = \text{Min}\,(R_{C/T}, RB_{T/D}, RG_{T/D})$



R_{WMS} - Rating for WMS

$R_{C/T}$ - Rating for (black water) C/T subsystem

$RB_{T/D}$ - Rating for black water T/D subsystem

$RG_{T/D}$ - Rating for gray water T/D subsystem

Data given in the form (not vessel dependent):

$Z_{C/T}, ZB_{T/D}, ZG_{T/D}$ } Attribute

$R_{C/T}, RB_{T/D}, RG_{T/D}$ } Ratings

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Con Anal.
✓		

(Continued)

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1					a, a, a	100						
2					a, b, a	70					N	A
3			N	A	a, b, a	70					N	A
4			N	A	a, b, a	70					N	A
5	N	A	N	A	a, b, b	70					N	A
6	N	A	N	A	a, a, b	70					N	A
7			N	A	a, b, a	70					N	A
8	N	A	N	A	a, b, b	70					N	A
9					a, a, a	100						
10					a, b, a	70					N	A
11			N	A	a, a, a	100						
12	N	A	N	A	a, a, b	70					N	A
13	N	A	N	A	a, b, b	70					N	A
14					a, a, a	100						
15					a, b, a	70					N	A
16					a, a, a	100						
17	N	A	N	A	a, a, b	70					N	A
18	N	A	N	A	a, b, b	70					N	A

Attribute Data ↑ ↑ Rating

N/A - Not a viable system/vessel combination

Definitions of $Z_{C/T}$, $ZB_{T/D}$, $ZG_{T/D}$

(a) No special or unique support equipment required by WMS subsystem.

(b) Some special or unique support equipment required by WMS subsystem; equipment requires only minimal and infrequent attention* to keep operational. (1)

(c) Some special and unique support equipment required by WMS subsystem; equipment requires more than infrequent attention to keep operational. (2)

NOTES: 1. E.g., firefighting equipment, special transformers, ozone detector for Grumman, bilge alarm for tanks.

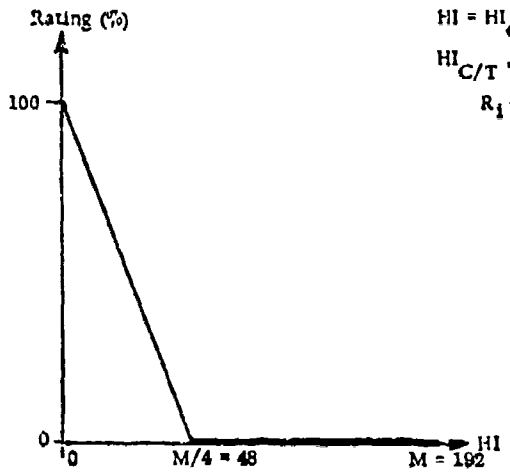
2. E.g., compressor installed to support WMS operation.

* No more frequently than weekly with a duration not greater then 10 minutes; or no more frequently than semi-annually with a duration of 2 hours.

M/L IV - PERSONNEL SAFETY

11 Hazard of contact with/spillage of toxic/dangerous substances * due to inherent WMS design

Effectiveness Rating Function



R_i (%) = 100 (1 - HI/48) for $0 \leq HI \leq 48$

= 0 for $48 < HI \leq 192$

$HI = HI_{C/T} + HIB_{T/D} + HIG_{T/D}$

$HI_{C/T}$, $HIB_{T/D}$, $HIG_{T/D} = L \times S \times C$

R_i (%) - Rating (%) of ith viable candidate WMS (independent of vessel)

HI - Hazard index for contact with/spillage of toxic/dangerous substances due to WMS inherent design

$HI_{C/T}$ - Hazard index for (black water) Collection/Transport subsystem

$HIB_{T/D}$ - Hazard index for black water Treatment/Dipsosal subsystem

$HIG_{T/D}$ - Hazard index for gray water Treatment/Disposal subsystem

L - Likelihood of hazard for C/T and T/D (black or gray) subsystems

S - Severity of hazard for C/T and T/D (black or gray) subsystems

C - Hazard correction for C/T and T/D (black or gray) subsystems

M - Maximum possible value of HI = 3 (4 x 4 x 4) = 192

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
✓		

* See Examples and Legend following.

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1					b,b,a/a,a,a /a,a,a	96						
2					b,a,a/c,a,a /a,a,a	94					N	A
3			N	A	b,a,a/c,a,a /a,a,a	94					N	A
4			N	A	a,a,a/b,b,a /a,a,a	96					N	A
5	N	A	N	A	a,a,a/b,b,a /b,a,a	94					N	A
6	N	A	N	A	b,b,a/a,a,a /b,a,a	94					N	A
7			N	A	b,b,a/b,a,a /a,a,a	94					N	A
8	N	A	N	A	b,b,a/b,a,a /b,a,a	92					N	A
9					b,a,a/a,a,a /a,a,a	98						
10					b,a,a/a,a,a /a,a,a	98					N	A
11			N	A	b,a,a/d,a,a /a,a,a	90						
12	N	A	N	A	b,a,a/a,a,a /b,a,a	96					N	A
13	N	A	N	A	b,a,a/a,a,a b,a,a	96					N	A
14					d,a,a/a,a,a /a,a,a	92						
15					d,a,a/a,a,a /a,a,a	92					N	A
16					d,a,a/d,a,a /a,a,a	83						
17	N	A	N	A	d,a,a/a,a,a /b,a,a	90					N	A
18	N	A	N	A	d,a,a/a,a,a /b,a,a	90					N	A

Attribute Data → ← Rating

N/A - Not a viable system/vessel combination

Definition and Values for L

(a) No chance (L = 0)
(b) Highly unlikely (L = 1)
(c) Fair to even chance (L = 2)
(d) Highly likely (L = 4)

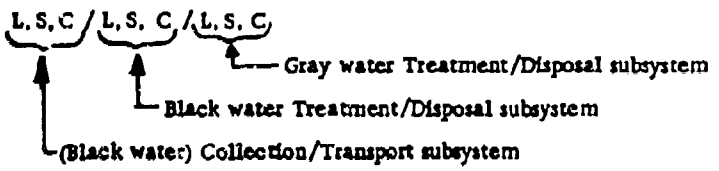
Definition and Values for S

(a) No resultant injury (S = 1)
(b) Results in injury of low to moderate severity (requiring first aid or limited medical treatment) (S = 2)
(c) Results in severe injury or death (S = 4)

Definition and Values for C

(a) Hazardous situation can be easily corrected (C = 1)
(b) Hazardous situation is difficult to correct (C = 2)
(c) Hazardous situation cannot be corrected (C = 4)

WMS data (independent of vessel) is given in the form:



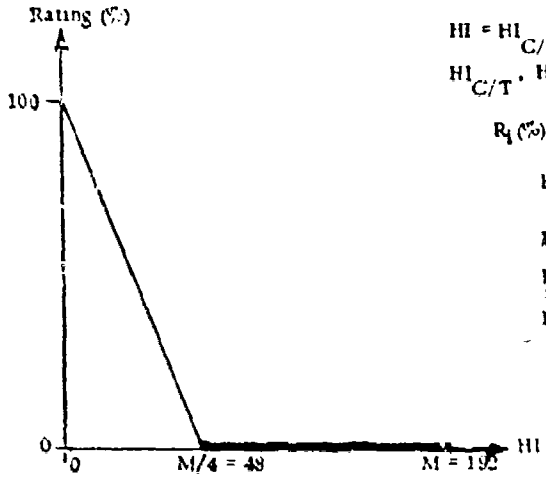
* Examples:

- Leakage of fumes from incinerator into adjacent berthing and working spaces.
- Hydrogen sulfide (a toxicant) may be generated in sewage holding tanks.
- Fresh water connections to MSD subsystems have a potential for contaminating the vessel's potable water supply with toxic/dangerous substances.
- Sewage contamination.
  - The following pathogens may be transmitted through sewage.
    - Tetanus (bacteria)
    - Typhoid (bacteria)
    - Dysentery (bacteria)
    - Cholera (bacteria)
    - Hepatitis (virus)
    - Polio (virus)
  - Possible methods of infection (a healthy person may be a carrier; infection hazard depends on a person's resistance).
    - Oral (from hands while smoking or eating) - the most common method of transmitting enteric (intestinal) diseases.
    - Through breaks in skin (cuts, abrasions, sores).
    - Eyes and nose (from hands).

M/E IV - PERSONNEL SAFETY

12 Hazard of contact with/spillage of toxic/dangerous substances* due to procedural errors/equipment failures of WMS

Effectiveness Rating Function



R_i (%) = 100 (1 - HI/48) for $0 \le HI \le 48$; = 0 for $48 < HI \le 192$

$HI = HI_{C/T} + HIB_{T/D} + HIG_{T/D}$

$HI_{C/T}, HIB_{T/D}, HIG_{T/D} = L \times S \times C$

R_i (%) - Rating (%) of ith viable candidate WMS (independent of vessel)

HI - Hazard index of contact with/spillage of toxic/dangerous substances due to procedural error/equipment failures of WMS

$HI_{C/T}$ - Hazard index for (black water) Collection/Transport subsystem

$HIB_{T/D}$ - Hazard index for black water Treatment/Disposal subsystem

$HIG_{T/D}$ - Hazard index for gray water Treatment/Disposal subsystem

L - Likelihood of hazard for C/T and T/D (black or gray) subsystems

S - Severity of hazard for C/T and T/D (black or gray) subsystems

C - Hazard correction for C/T and T/D (black or gray) subsystems

M - Maximum possible value of HI = 3 (4 x 4 x 4) = 192

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
✓		

* See Examples and Legend following.

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1					b,b,a/b,a,a /b,a,a	92						
2					c,b,b/c,b,b /b,a,a	65					N	A
3			N	A	c,b,b/c,b,b /b,a,a	65					N	A
4			N	A	b,b,a/c,a,a /b,a,a	90					N	A
5	N	A	N	A	b,b,a/c,a,a, /c,a,a	88					N	A
6	N	A	N	A	b,b,a/b,a,a /c,a,a	90					N	A
7			N	A	b,b,a/c,a,a /b,a,a	90					N	A
8	N	A	N	A	b,b,a/c,a,a /c,a,a	88					N	A
9					b,a,a/b,a,a /b,a,a	94						
10					b,a,a/b,a,a /b,a,a	94					N	A
11			N	A	b,a,a/c,a,a /b,a,a	92						
12	N	A	N	A	b,a,a/b,a,a /c,a,a	92					N	A
13	N	A	N	A	b,a,a/b,a,a /c,a,a	92					N	A
14					b,a,a/b,a,a /b,a,a	94						
15					b,a,a/b,a,a /b,a,a	94					N	A
16					b,a,a/c,a,a /b,a,a	92						
17	N	A	N	A	b,a,a/b,a,a /c,a,a	92					N	A
18	N	A	N	A	b,a,a/b,a,a /c,a,a	92					N	A

Attribute Data ↑ ↑ Rating

N/A - Not a viable system/vessel combination

Definition and Values for L

(a) No chance (L = 0)
(b) Very unlikely (L = 1)
(c) Up to even chance (L = 2)
(d) Highly likely (L = 4)

Definition and Values for S

(a) No resultant injury (S = 1)
(b) Results in injury of low to moderate severity (requiring first aid or limited medical treatment) (S = 2)
(c) Results in severe injury or death (S = 4)

Definition and Values for C

(a) Hazardous situation can be easily corrected (C = 1)
(b) Hazardous situation is difficult to correct (C = 2)
(c) Hazardous situation cannot be corrected (C = 4)

WMS data (independent of vessel) is given in the form:

L, S, C / L, S, C / L, S, C

- L, S, C — Gray water Treatment/Disposal subsystem
- L, S, C — Black water Treatment/Disposal subsystem
- L, S, C — (Black water) Collection/Transport subsystem

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* Examples:

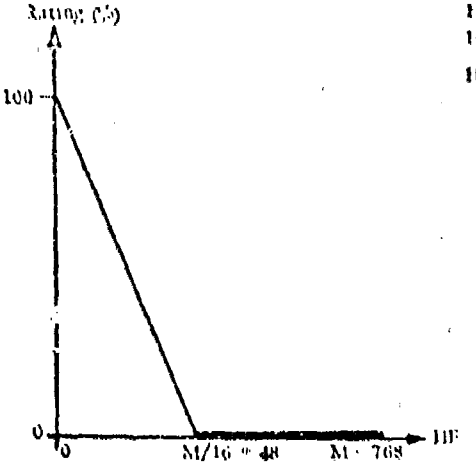
- Leakage of fumes from incinerator into adjacent berthing and working spaces.
- Hydrogen sulfide (a toxicant) may be generated in sewage holding tanks.
- Fresh water connections to MSD subsystems have a potential for contaminating the vessel's potable water supply with toxic/dangerous substances.
- Sewage contamination.
  - The following pathogens may be transmitted through sewage.
    - Tetanus (bacteria)
    - Typhoid (bacteria)
    - Dysentery (bacteria)
    - Cholera (bacteria)
    - Hepatitis (virus)
    - Polio (virus)
  - Possible methods of infection (a healthy person may be a carrier; infection hazard depends on a person's resistance).
    - Oral (from hands while smoking or eating) - the most common method of transmitting enteric (intestinal) diseases.
    - Through breaks in skin (cuts, abrasions, sores).
    - Eyes and nose (from hands).

M/C IV - PERSONNEL SAFETY

21 Hazard of explosive potential for operator/maintainer due to inherent WMS design

Effectiveness Rating Function

$R_{iv}(\%) = 100\ (1-HF/48)$	$0 \leq HF \leq 48$
$= 0$	$48 < HF \leq 768$



$HF = I \times HI$

$HI = HI_{C/T} + HIB_{T/D} + HIG_{T/D}$

$HI_{C/T}, HIB_{T/D}, HIG_{T/D} = L \times S \times C$

$R_{iv}(\%)$ = Rating (%) of ith viable candidate WMS on vessel v

HF = Hazard factor for explosive potential for operator/maintainer due inherent WMS design and installation

I = Installation index (for personnel safety)

HI = Hazard index for WMS

$HI_{C/T}$ = Hazard index for (black water) Collection/Transport subsystem

$HIB_{T/D}$ = Hazard index for black water Treatment/Disposal subsystem

$HIG_{T/D}$ = Hazard index for gray water Treatment/Disposal subsystem

L = Likelihood of hazard for C/T and T/D (black or gray) subsystems

S = Severity of hazard for C/T and T/D (black or gray) subsystems

C = Hazard correction for C/T and T/D (black or gray) subsystem

M = Maximum possible value of HF = 4 (3) (4 x 4 x 4) = 768 (Continued)

Source of Data		
NSD Anal.	WMS Install. Anal.	WMS Con Anal.
✓	✓	

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	a/	100	a/	100	a/a,a,a/a,a,a /a,a,a	100	a/	100	a/	100	a/	100
2	a/	100	a/	100	a/a,a,a/a,a,a /a,a,a	100	a/	100	a/	100	N	A
3	b/	96	N	A	b/a,a,a/b,a,a /a,a,a	96	b/	96	a/	98	N	A
4	a/	100	N	A	a/a,a,a/a,a,a /a,a,a	100	a/	100	a/	100	N	A
5	N	A	N	A	a/a,a,a/a,a,a /a,a,a	100	a/	100	a/	100	N	A
6	N	A	N	A	a/a,a,a/a,a,a /a,a,a	100	a/	100	a/	100	N	A
7	b/	92	N	A	b/a,a,a/b,b,b /a,a,a	92	b/	92	c/	67	N	A
8	N	A	N	A	b/a,a,a/b,b,b /b,b,b	67	b/	67	c/	33	N	A
9	a/	100	a/	100	a/a,a,a/a,a,a /a,a,a	100	a/	100	a/	100	a/	100
10	b/	96	c/	92	b/a,a,a/b,a,a /a,a,a	96	b/	96	a/	98	N	A
11	a/	96	N	A	a/a,a,a/b,b,a /a,a,a	96	a/	96	a/	96	a/	96
12	N	A	N	A	a/a,a,a/a,a,a /a,a,a	100	a/	100	a/	100	N	A
13	N	A	N	A	b/a,a,a/b,a,a /b,b,b	79	b/	79	c/	58	N	A
14	a/	100	a/	100	a/a,a,a/a,a,a /a,a,a	100	a/	100	a/	100	a/	100
15	b/	96	c/	92	b/a,a,a/b,a,a /a,a,a	96	b/	96	b/	96	N	A
16	a/	96	a/	96	a/a,a,a/b,b,a /a,a,a	96	a/	96	a/	96	a/	96
17	N	A	N	A	a/a,a,a/a,a,a /a,a,a	100	a/	100	a/	100	N	A
18	N	A	N	A	b/a,a,a/b,b,a /b,b,b	75	b/	75	c/	50	N	A

Attribute Data — Rating

N/A - Not a viable system/vessel combination

Definition and Values for I

(a) Likelihood of hazardous situation is not increased due to location of any portion of WMS (I = 1)

(b) Likelihood of hazardous situation is increased due to proximity of any portion of WMS to working or berthing area (I = 2)

(c) Likelihood of hazardous situation is increased due to proximity of any portion of WMS to fuel storage area (I = 4)

Definition and Values for L

(a) No chance (L = 0)

(b) Highly ynlikely (L = 1)

(c) Fair to even chance (L = 2)

(d) Highly likely (L = 4)

Definition and Values for S

(a) No resultant injury (S = 1)

(b) Results in injury of low to moderate severity (requiring first aid or limited medical treatment) (S = 2)

(c) Results in severe injury or death (S = 4)

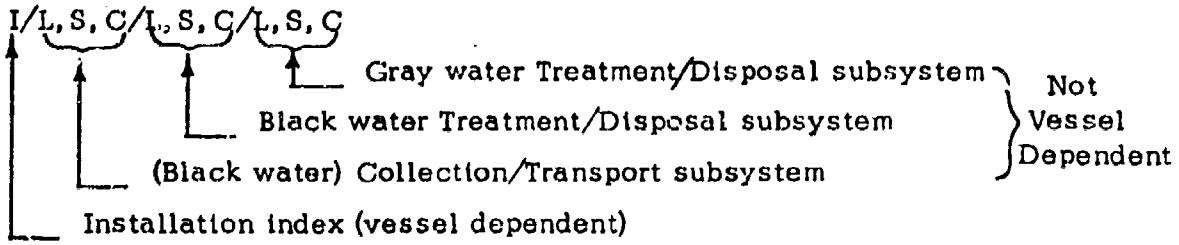
Definition and Values for C

(a) Hazardous situation can be easily corrected (C = 1)

(b) Hazardous situation is difficult to correct (C = 2)

(c) Hazardous situation cannot be corrected (C = 4)

WMS/vessel data is given in the form

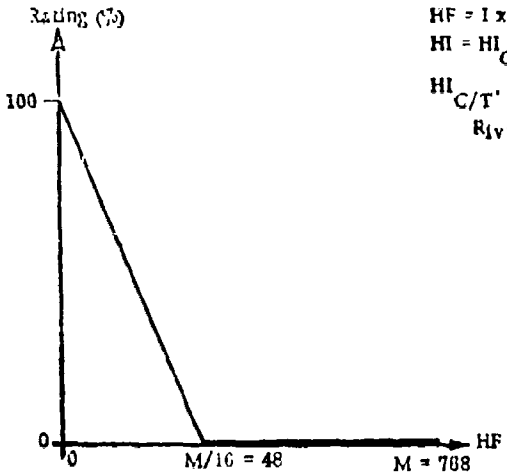


EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E IV - PERSONNEL SAFETY

22	Hazard of explosive potential for operator/maintainer due to procedural error/equipment failures of WMS

Effectiveness Rating Function



$R_{Iv}(\%) = 100\ (1 - HF/48)$ for $0 \le HF \le 48$; $= 0$ for $48 < HF \le 768$

$HF = I \times HI$

$HI = HI_{C/T} + HIB_{T/D} + HIG_{T/D}$

$HI_{C/T},\ HIB_{T/D},\ HIG_{T/D} = L \times S \times C$

$R_{Iv}(\%)$ - Rating (%) of ith viable candidate WMS on vessel v

HF - Hazard factor for explosive potential for operator/maintainer due to procedural errors/equipment failures of WMS and installation

I - Installation index (for personnel safety)

HI - Hazard index for WMS

$HI_{C/T}$ - Hazard index for (black water) Collection/Transport subsystem

$HIB_{T/D}$ - Hazard index for black water Treatment/Disposal subsystem

$HIG_{T/D}$ - Hazard index for gray water Treatment/Disposal subsystem

L - Likelihood of hazard for C/T and T/D (black or gray) subsystems

S - Severity of hazard for C/T and T/D (black or gray) subsystems

C - Hazard correction for C/T and T/D (black or gray) subsystems

M - Maximum possible value of HF = 4 (3) (4 x 4 x 4) = 768 (Continued)

Source of Data		
MSD Anal.	WMS Tradeoff Anal.	WMS Cost Anal.
✓	✓	

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	c/	83	a/	83	a/a,a,a/b,b,b /b,b,b	83	a/	83	a/	83	a/	83
2	a/	88	a/	88	a/b,b,a/a,a,a /b,b,b	88	a/	88	a/	88	N	A
3	b/	58	N	A	b/b,b,a/c,b,a /b,b,b	58	b/	58	a/	79	N	A
4	a/	83	N	A	a/b,b,b/a,a,a /b,b,b	83	a/	83	a/	83	N	A
5	N	A	N	A	a/b,b,b/a,a,a /a,a,a	92	a/	92	a/	92	N	A
6	N	A	N	A	a/a,a,a/b,b,b /a,a,a	92	a/	92	a/	92	N	A
7	b/	0	N	A	b/b,b,b/c,c,b /b,b,b	0	b/	0	c/	0	N	A
8	N	A	N	A	b/b,b,b/c,c,b /c,c,b	0	b/	0	c/	0	N	A
9	a/	41	a/	81	a/b,a,a/ b,b,b/b,b,b	81	a/	81	a/	81	a/	81
10	b/	75	c/	50	b/b,a,a/ b,a,a/b,b,b	75	b/	75	a/	88	N	A
11	a/	81	N	A	a/b,a,a/c,b,a /b,b,b	81	a/	81	a/	81	a/	81
12	N	A	N	A	a/b,a,a/b,b,b /a,a,a	90	a/	90	a/	90	N	A
13	N	A	N	A	b/b,a,a/b,a,a /c,c,b	25	b/	25	c/	0	N	A
14	a/	83	a/	83	a/a,a,a/b,b,b /b,b,b	83	a/	83	a/	83	a/	83
15	b/	79	c/	58	b/a,a,a/b,a,a /b,b,b	79	b/	79	b/	79	N	A
16	a/	83	a/	83	a/a,a,a/c,b,a /b,b,b	83	a/	83	a/	83	a/	83
17	N	A	N	A	a/a,a,a/b,b,b /a,a,a	92	a/	92	a/	92	N	A
18	N	A	N	A	b/a,a,a/b,a,a /c,c,b	63	c/	63	c/	25	N	A

Attribute Data ↑ ↑ Rating

N/A - No a viable system/vessel combination

Definition and Values for I

(a) Likelihood of hazardous situation is not increased due to location of any portion of WMS (I = 1)

(b) Likelihood of hazardous situation is increased due to proximity of any portion of WMS to working or berthing area (I = 2)

(c) Likelihood of hazardous situation is increased due to proximity of any portion of WMS to fuel storage area (I = 4)

Definition and Values for L

(a) No chance (L = 0)

(b) Highly ynlikely (L = 1)

(c) Fair to even chance (L = 2)

(d) Highly likely (L = 4)

Definition and Values for S

(a) No resultant injury (S = 1)

(b) Results in injury of low to moderate severity (requiring first aid or limited medical treatment) (S = 2)

(c) Results in severe injury or death (S = 4)

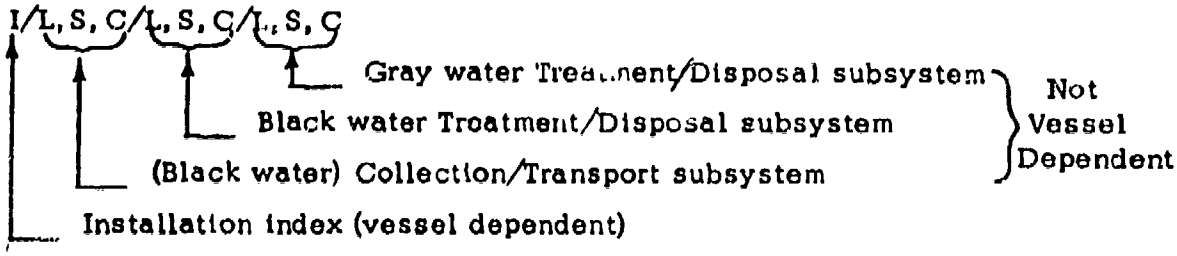
Definition and Values for C

(a) Hazardous situation can be easily corrected (C = 1)

(b) Hazardous situation is difficult to correct (C = 2)

(c) Hazardous situation cannot be corrected (C = 4)

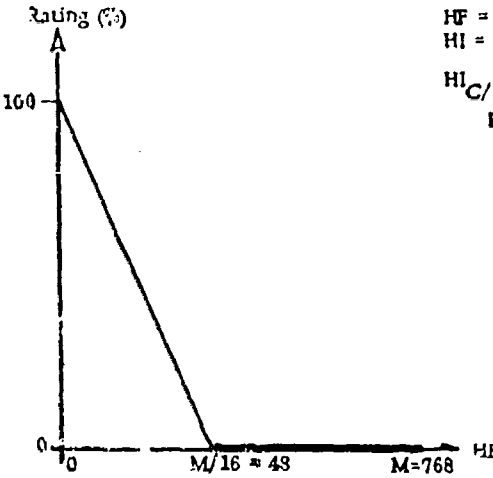
WMS/vessel data is given in the form



M/E IV - PERSONNEL SAFETY

31 Hazard of fire ignition potential* due to inherent WMS design

Effectiveness Rating Function



R_{iv} (%) = 100 (1 - HF/48) for $0 \le HF \le 48$; = 0 for $48 < HF \le 768$

$HF = I \times HI$

$HI = HI_{C/T} + HIB_{T/D} + HIG_{T/D}$

$HI_{C/T}, HIB_{T/D}, HIG_{T/D} = L \times S \times C$

R_{iv}(%) - Rating (%) of ith viable candidate WMS on vessel v

HF - Hazard factor for fire ignition potential due to WMS inherent design and installation

I - Installation index (for personnel safety)

HI - Hazard index for WMS

$HI_{C/T}$ - Hazard index for (black water) Collection/Transport subsystem

$HIB_{T/D}$ - Hazard index for black water Treatment/Disposal subsystem

$HIG_{T/D}$ - Hazard index for gray water Treatment/Disposal subsystem

L - Likelihood of hazard for C/T and T/D (black or gray) subsystems

S - Severity of hazard for C/T and T/D (black or gray) subsystems

C - Hazard correction for C/T and T/D (black or gray) subsystems

M - Maximum possible value of HF = 4 (3) (4 x 4 x 4) = 768

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
✓	✓	

(Continued)

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	a/	100	a/	100	a/a,a,a/a,a,a /a,a,a	100	a/	100	a/	100	a/	100
2	a/	75	a/	75	a/c,b,a/c,b,b /a,a,a	75	a/	75	a/	75	N	A
3	b/	67	N	A	b/c,b,a/c,b,a /a,a,a	67	b/	67	a/	83	N	A
4	a/	100	N	A	a/a,a,a/a,a,a /a,a,a	100	a/	100	a/	100	N	A
5	N	A	N	A	a/a,a,a/a,a,a /a,a,a	100	a/	100	a/	100	N	A
6	N	A	N	A	a/a,a,a/a,a,a /a,a,a	100	a/	100	a/	100	N	A
7	b/	83	N	A	b/a,a,a/b,b,b /a,a,a	83	b/	83	c/	67	N	A
8	N	A	N	A	b/a,a,a/b,b,b /b,b,b	67	b/	67	c/	33	N	A
9	a/	100	a/	100	a/a,a,a/a,a,a /a,a,a	100	a/	100	a/	100	a/	100
10	b/	96	c/	92	b/a,a,a/b,a,a /a,a,a	96	b/	96	a/	98	N	A
11	a/	98	N	A	a/a,a,a/b,a,a /a,a,a	98	a/	98	a/	98	a/	92
12	N	A	N	A	a/a,a,a/a,a,a /a,a,a	100	a/	100	a/	100	N	A
13	N	A	N	A	b/a,a,a/b,a,a /b,b,b	79	b/	79	c/	58	N	A
14	a/	100	a/	100	a/a,a,a/a,a,a /a,a,a	100	a/	100	a/	100	a/	100
15	b/	96	c/	92	b/a,a,a/b,a,a /a,a,a	96	b/	96	b/	96	N	A
16	a/	98	a/	98	a/a,a,a/b,a,a /a,a,a	98	a/	98	a/	98	a/	98
17	N	A	N	A	a/a,a,a/a,a,a /a,a,a	100	a/	100	a/	100	N	A
18	N	A	N	A	b/a,a,a/b,a,a /b,b,b	79	b/	79	c/	58	N	A

Attribute Data — Rating

N/A - Not a viable system/vessel combination

Definition and Values for I

(a) Likelihood of hazardous situation is not increased due to location of any portion of WMS (I = 1)

(b) Likelihood of hazardous situation is increased due to proximity of any portion of WMS to working or berthing area (I = 2)

(c) Likelihood of hazardous situation is increased due to proximity of any portion of WMS to fuel storage area (I = 4)

Definition and Values for L

(a) No chance (L = 0)

(b) Highly ynlikely (L = 1)

(c) Fair to even chance (L = 2)

(d) Highly likely (L = 4)

Definition and Values for S

(a) No resultant injury (S = 1)

(b) Results in injury of low to moderate severity (requiring first aid or limited medical treatment) (S = 2)

(c) Results in severe injury or death (S = 4)

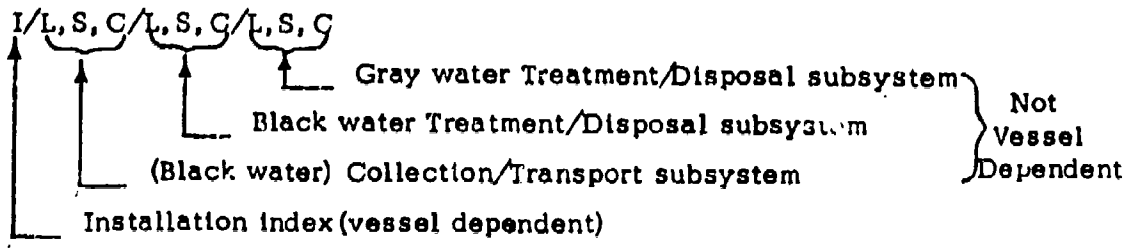
Definition and Values for C

(a) Hazardous situation can be easily corrected (C = 1)

(b) Hazardous situation is difficult to correct (C = 2)

(c) Hazardous situation cannot be corrected (C = 4)

WMS/vessel data is given in the form



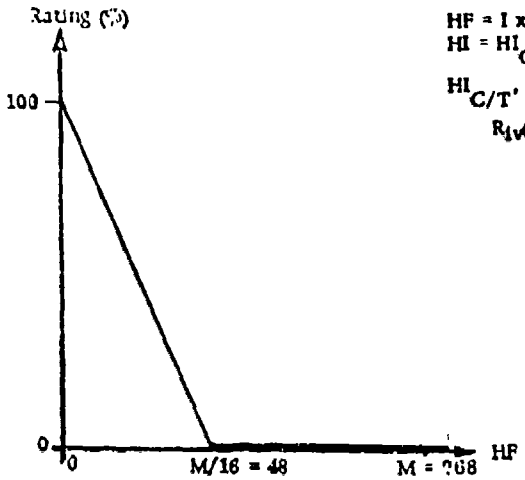
* Oil used for flushing (in Chrysler) is not flammable under ordinary conditions. However, at high temperatures, e.g., in the presence of a fire, it will support combustion.

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E IV - PERSONNEL SAFETY

32 Hazard of fire ignition potential* due to procedural errors/equipment failure of WMS

Effectiveness Rating Function



R_{1v} (%) = 100 (1 - HF/48) $0 \le HF \le 48$

= 0 $48 < HF \le 768$

HF = I x HI

$HI = HI_{C/T} + HIB_{T/D} + HIG_{T/D}$

$HI_{C/T}, HIB_{T/D}, HIG_{T/D} = L \times S \times C$

R_{1v}(%) - Rating (%) of ith viable candidate WMS on vessel v

HF - Hazard factor for fire ignition potential due to procedural errors/equipment failures of WMS

I - Installation index (for personnel safety)

HI - Hazard index for WMS

$HI_{C/T}$ - Hazard index for (black water) Collection/Transport subsystem

$HIB_{T/D}$ - Hazard index for black water Treatment/Disposal subsystem

$HIG_{T/D}$ - Hazard index for gray water Treatment/Disposal subsystem

L - Likelihood of hazard for C/T and T/D (black or gray) subsystems

S - Severity of hazard for C/T and T/D (black or gray) subsystems

C - Hazard correction for C/T and T/D (black or gray) subsystems

M - Maximum possible value of HF = 4(3) (4 x 4 x 4) = 768 (Continued)

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Con Anal.
✓	✓	

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	a/	83	a/	83	a/a,a,a/b,b,b /b,b,b	83	a/	83	a/	83	a/	83
2	a/	58	a/	58	a/c,b,b/c,b,b /b,b,b	58	a/	58	a/	58	N	A
3	b/	17	N	A	b/c,b,b/c,b,b /b,b,b	17	b/	17	a/	58	N	A
4	a/	81	N	A	a/b,b,b/b,a,a /b,b,b	81	a/	81	a/	81	N	A
5	N	A	N	A	a/b,b,b/b,a,a /b,a,a	88	a/	88	a/	88	N	A
6	N	A	N	A	a/a,a,a/b,b,b /b,a,a	90	a/	90	a/	90	N	A
7	b/	0	N	A	b/b,b,b/c,c,b /b,b,b	0	b/	0	c/	0	N	A
8	N	A	N	A	b/b,b,b/c,c,b /c,c,b	0	b/	0	c/	0	N	A
9	a/	83	a/	83	a/a,a,a/b,b,b /b,b,b	83	a/	83	a/	83	a/	83
10	b/	67	c/	33	b/a,a,a/b,b,b /b,b,b	67	b/	67	a/	83	N	A
11	a/	90	N	A	a/a,a,a/b,a,a b,b,b	90	a/	90	a/	90	a/	90
12	N	A	N	A	a/a,a,a/b,b,b /b,a,a	90	a/	90	a/	90	N	A
13	N	A	N	A	b/a,a,a/b,b,b /c,c,b	17	b/	17	c/	0	N	A
14	a/	83	a/	83	a/a,a,a/b,b,b /b,b,b	83	a/	83	a/	83	a/	83
15	b/	67	c/	33	b/a,a,a/b,b,b /b,b,b	67	b/	67	b/	67	N	A
16	a/	90	a/	90	a/a,a,a/b,a,a, /b,b,b	90	a/	90	a/	90	a/	90
17	N	A	N	A	a/a,a,a/b,b,b /b,a,a	90	a/	90	c/	50	N	A
18	N	A	N	A	b/a,a,a/b,b,b /c,c,b	17	b/	17	c/	0	N	A

Attribute Data ↑ ↑ Rating

N/A - Not a viable system/vessel combination

Definition and Values for I

(a) Likelihood of hazardous situation is not increased due to location of any portion of WMS (I = 1)

(b) Likelihood of hazardous situation is increased due to proximity of any portion of WMS to working or berthing area (I = 2)

(c) Likelihood of hazardous situation is increased due to proximity of any portion of WMS to fuel storage area (I = 4)

Definition and Values for L

(a) No chance (L = 0)

(b) Highly ynlikely (L = 1)

(c) Fair to even chance (L = 2)

(d) Highly likely (L = 4)

Definition and Values for S

(a) No resultant injury (S = 1)

(b) Results in injury of low to moderate severity (requiring first aid or limited medical treatment) (S = 2)

(c) Results in severe injury or death (S = 4)

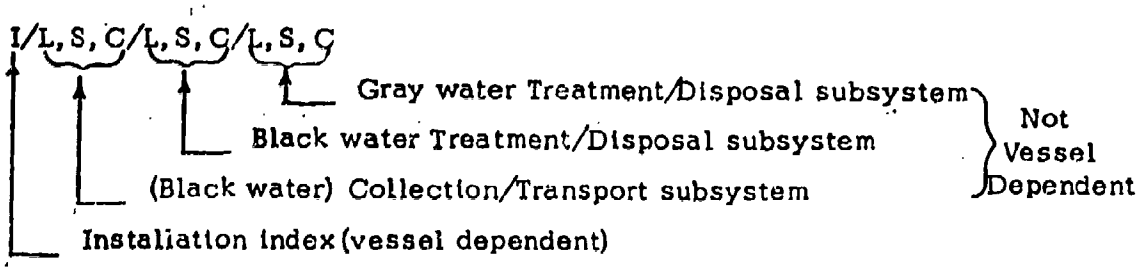
Definition and Values for C

(a) Hazardous situation can be easily corrected (C = 1)

(b) Hazardous situation is difficult to correct (C = 2)

(c) Hazardous situation cannot be corrected (C = 4)

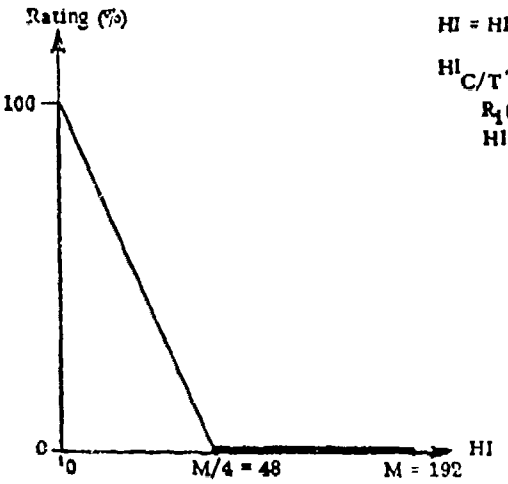
WMS/vessel data is given in the form



* Oil used for flushing (in Chrysler) is not flammable under ordinary conditions. However, at high temperatures, e.g., in the presence of a fire, it will support combustion.

4	Hazard of electric shock potential * for operator/maintainer of WMS

Effectiveness Rating Function



R_i (%) = 100 (1 - HI/48)	$0 \leq HI \leq 48$
= 0	$48 < HI \leq 192$

$HI = HI_{C/T} + HIB_{T/D} + HIB_{T/D}$

$HI_{C/T}, HIB_{T/D}, HIG_{T/D} = L \times S \times C$

R_i (%) - Rating (%) of ith viable candidate WMS (independent of vessel)

HI HI - Hazard index for electric shock potential for operator/maintainer of WMS

$HI_{C/T}$ - Hazard index for (black water) Collection/Transport subsystem

$HIB_{T/D}$ - Hazard index for balck water Treatment/Disposal subsystem

$HIG_{T/D}$ - Hazard index for gray water Treatment/Disposal subsystem

L - Likelihood of hazard for C/T and T/D (black or gray) subsystems

S - Severity of hazard for C/T and T/D (black or gray) subsystems

C - Hazard correction for C/T and T/D (black or gray) subsystems

M - Maximum possible value of HI = 3 (4 x 4 x 4) = 192

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
✓		

(Continued)

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1					a,a,a/b,b,a / b,b,a	92						
2					a,a,a/b,b,a /b,b,a	92					N	A
3			N	A	a,a,a/b,b,a /b,b,a	92					N	A
4			N	A	b,b,a/b,b,a /b,b,a	88					N	A
5	N	A	N	A	b,b,a/b,b,a /b,b,a	88					N	A
6	N	A	N	A	a,a,a/b,b,a /b,b,a	92					N	A
7			N	A	b,b,a/b,b,a /b,b,a	88					N	A
8	N	A	N	A	b,b,a/b,b,a /b,b,a	88					N	A
9					b,a,a/b,b,a / b,b,a	90						
10					b,a,a/b,a,a /b,b,a	92					N	A
11			N	A	b,a,a/b,c,a /b,b,a	85						
12	N	A	N	A	b,a,a/b,b,a /b,b,a	90					N	A
13	N	A	N	A	b,a,a/b,a,a /b,b,a	92					N	A
14					b,b,a/b,b,a /b,b,a	88						
15					b,b,a/b,a,a /b,b,a	90					N	A
16					b,b,a/b,c,a /b,b,a	83						
17	N	A	N	A	b,b,a/b,b,a /b,b,a	88					N	A
18	N	A	N	A	b,b,a/b,a,a /b,b,a	90					N	A

Attribute Data — Rating

N/A - Not a viable system/vessel combination

IV - 4

Definition and Values for L

(a) No chance (L = 0)

(b) Highly unlikely (L = 1)

(c) Fair to even chance (L = 2)

(d) Higly likely (L = 4)

Definition and Values for S

(a) No resultant injury (S = 1)

(b) Results in injury of low to moderate severity (requiring first aid or limited medical treatment) (S = 2)

(c) Results in severe injury or death (S = 4)

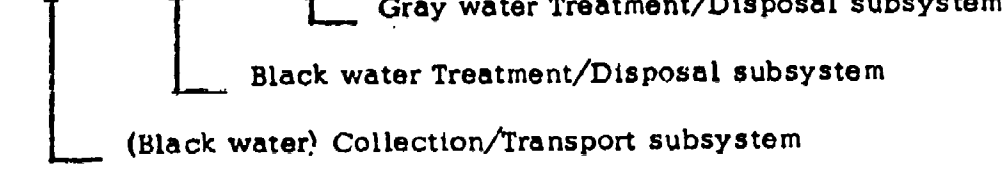
Definition and Values for C

(a) Hazardous situation can be easily corrected (C = 1)

(b) Hazardous situation is difficult to correct (C = 2)

(c) Hazardous situation cannot be corrected (C = 4)

WMS data (independent of vessel) is given in the form



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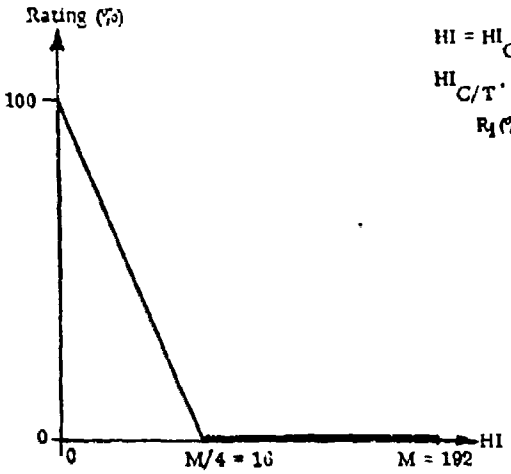
* Electric shock may result in severe burns and/or death; in addition, reaction to electric shock may cause affected individual to be thrown aside, possibly subjecting him to severe impact injuries and/or contact with sharp edges/hot surfaces.

51 Physical hazards associated with WMS due to sharp edges*

Effectiveness Rating Function



$R_i(\%) = 100\ (1 - HI/48)$ for $0 \le HI \le 48$; $= 0$ for $48 < HI \le 192$

$HI = HI_{C/T} + HIB_{T/D} + HIG_{T/D}$

$HI_{C/T}, HIB_{T/D}, HIG_{T/D} = L \times S \times C$

$R_i(\%)$ - Rating (%) of ith viable candicate WMS (independent of vessel)

HI - Hazard index for physical hazards associated with WMS due to sharp edges

$HI_{C/T}$ - Hazard index for (black water) Collection/Transport subsystem

$HIB_{T/D}$ - Hazard index for black water Treatment/Disposal subsystem

$HIG_{T/D}$ - Hazard index for gray water Treatment/Disposal subsystem

L - Likelihood of hazard for C/T and T/D (black or gray) subsystems

S - Severity of hazard for C/T and T/D (black or gray) subsystems

C - Hazard correction for C/T and T/D (black or gray) subsystems

M - Maximum possible value of HI = 3 (4 x 4 x 4) = 192

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Ops Anal.
✓		

(Continued)

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1					a,a,a/a,a,a /a,a,a	100						
2					a,a,a/a,a,a /a,a,a	100					N	A
3			N	A	a,a,a/a,a,a /a,a,a	100					N	A
4			N	A	a,a,a/a,a,a /a,a,a	100					N	A
5	N	A	N	A	a,a,a/a,a,a /a,a,a	100					N	A
6	N	A	N	A	a,a,a/a,a,a /a,a,a	100					N	A
7			N	A	a,a,a/a,a,a /a,a,a	100					N	A
8	N	A	N	A	a,a,a/a,a,a /a,a,a	100					N	A
9					b,a,a/a,a,a /a,a,a	98						
10					b,a,a/b,a,a /a,a,a	96					N	A
11			N	A	b,a,a/c,b,a /a,a,a	90						
12	N	A	N	A	b,a,a/a,a,a /a,a,a	98					N	A
13	N	A	N	A	b,a,a/b,a,a /a,a,a	96					N	A
14					b,a,a/a,a,a /a,a,a	98						
15					b,a,a/b,a,a /a,a,a	96					N	A
16					b,a,a/c,b,a /a,a,a	90						
17	N	A	N	A	b,a,a/a,a,a /a,a,a	98					N	A
18	N	A	N	A	b,a,a/b,a,a /a,a,a	96					N	A

Attribute Data → ← Rating

N/A - Not a viable system/vessel combination

Definition and Values for L

(a) No chance (L = 0)

(b) Highly unlikely (L = 1)

(c) Fair to even chance (L = 2)

(d) Higly likely (L = 4)

Definition and Values for S

(a) No resultant injury (S = 1)

(b) Results in injury of low to moderate severity (requiring first aid or limited medical treatment) (S = 2)

(c) Results in severe injury or death (S = 4)

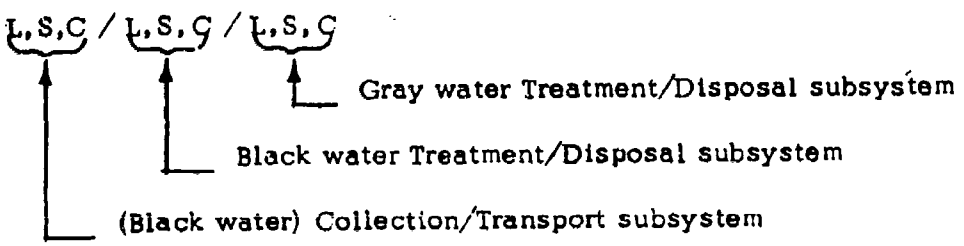
Definition and Values for C

(a) Hazardous situation can be easily corrected (C = 1)

(b) Hazardous situation is difficult to correct (C = 2)

(c) Hazardous situation cannot be corrected (C = 4)

WMS data (independent of vessel) is given in the form:



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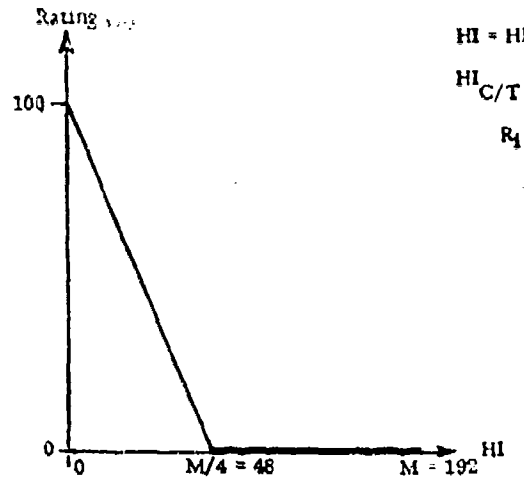
* Combined effect of injury due to sharp edges/points and sewage contamination may introduce harmful pathogens into the bloodstream of an affected individual.

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E IV - PERSONNEL SAFETY

52	Physical hazards associated with WMS due to hot surfaces

Effectiveness Rating Function



R_i (%) = 100 (1 - HI/48)	$0 \le HI \le 48$
= 0	$48 < HI \le 192$

$HI = HI_{C/T} + HIB_{T/D} + HIG_{T/D}$

$HI_{C/T}, HIB_{T/D}, HIG_{T/D} = L \times S \times C$

R_i(%) - Rating (%) of ith viable candidate WMS (independent of vessel)

HI - Hazard index for physical hazards associated with WMS due to hot surfaces

$HI_{C/T}$ - Hazard index for (black water) Collection/Transport subsystem

$HIB_{C/T}$ - Hazard index for blackwater Treatment/Disposal subsystem

$HIG_{C/T}$ - Hazard index for gray water Treatment/Disposal subsystem

L - Likelihood hazard for C/T and T/D (black or gray) subsystems

S - Severity of hazard for C/T and T/D (black or gray) subsystems

C - Hazard correction for C/T and T/D (black or gray) subsystems

M - Maximum possible value of HI = 3 (4 x 4 x 4) = 192

Source of Data		
MSC Anal.	WMS Install. Anal.	WMS Cost Anal.
✓		

(Continued)

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1					a,a,a/a,a,a /a,a,a	100						
2					a,a,a/a,a,a /a,a,a	100					N	A
3			N	A	a,a,a/b,b,a /a,a,a	96					N	A
4			N	A	a,a,a/b,b,a /a,a,a	96					N	A
5	N	A	N	A	a,a,a/b,b,a /b,b,a	92					N	A
6	N	A	N	A	a,a,a/a,a,a /b,b,a	96					N	A
7			N	A	a,a,a/c,b,a /a,a,a	92					N	A
8	N	A	N	A	a,a,a/c,b,a /c,b,a	83					N	A
9					b,a,a/a,a,a /a,a,a	88						
10					b,a,a/c,b,a /a,a,a	88					N	A
11			N	A	b,a,a/c,b,a /a,a,a	88						
12	N	A	N	A	b,a,a/a,a,a /b,b,a	94					N	A
13	N	A	N	A	b,a,a/c,b,a /c,b,a	81					N	A
14					b,a,a/a,a,a /a,a,a	98						
15					b,a,a/c,b,a /a,a,a	88					N	A
16					b,a,a/c,b,a /a,a,a	88						
17	N	A	N	A	b,a,a/a,a,a /b,b,a	94					N	A
18	N	A	N	A	b,b,a/c,b,a /c,b,a	81					N	A

Attribute Data ↑ ↑ Rating

N/A - Not a viable system/vessel combination

Definition and Values for L

(a) No chance (L = 0)

(b) Highly unlikely (L = 1)

(c) Fair to even chance (L = 2)

(d) Higly likely (L = 4)

Definition and Values for S

(a) No resultant injury (S = 1)

(b) Results in injury of low to moderate severity (requiring first aid or limited medical treatment) (S = 2)

(c) Results in severe injury or death (S = 4)

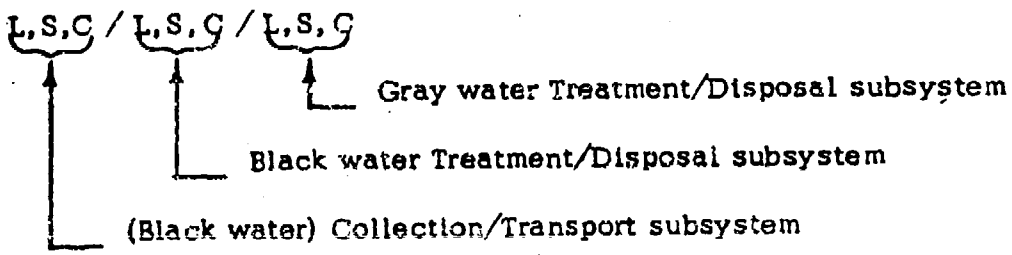
Definition and Values for C

(a) Hazardous situation can be easily corrected (C = 1)

(b) Hazardous situation is difficult to correct (C = 2)

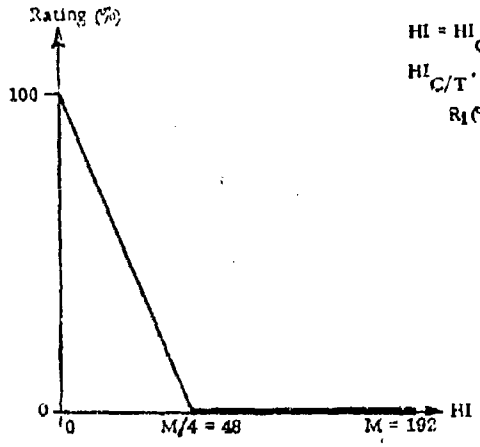
(c) Hazardous situation cannot be corrected (C = 4)

WMS data (independent of vessel) is given in the form



53 Physical hazards for WMS maintainer due to rotating machinery

Effectiveness Rating Function



R_i (%) = 100 (1 - HI/48) for $0 \le HI \le 48$; = 0 for $48 < HI \le 192$

$HI = HI_{C/T} + HIB_{T/D} + HIG_{T/D}$

$HI_{C/T}, HIB_{T/D}, HIG_{T/D} = L \times S \times C$

R_i (%) - Rating (%) of ith viable candidate WMS (independent of vessel)

HI - Hazard index for physical hazards for WMS maintainer due to rotating machenery

$HI_{C/T}$ - Hazard index for (black water) Collection/Transport subsystem

$HIB_{T/D}$ - Hazard index for black water Treatmen/Disposal subsystem

$HIG_{T/D}$ - Hazard index for gray water Treatment/Disposal subsystem

L - Likelihood of hazard for C/T and T/D (black or gray) subsystems

S - Severity of hazard for T/C and T/D (black or gray) subsystems

C - Hazard correction for C/T and T/D (black or gray) subsystems

M - Maximum possible value of HI = 3 (4 x 4 x 4) = 192

Source of Data		
MSD Anal.	WMS Install. Anal	WMS Con Anal.
✓		

(Continued)

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1					a,a,a/b,b,a /b,b,a	92						
2					a,a,a,/b,b,a /b,b,a	92					N	A
3			N	A	a,a,a/b,b,a /b,b,a	92					N	A
4			N	A	b,b,a/ b,b,a /b,b,a	88					N	A
5	N	A	N	A	b,b,a/b,b,a /b,b,a	88					N	A
6	N	A	N	A	a,a,a,/b,b,a /b,b,a	92					N	A
7			N	A	b,b,a/c,b,a /b,b,a	83					N	A
8	N	A	N	A	b,b,a/c,b,a /b,a	79					N	A
9					c,b,a/b,b,a /b,b,a	83						
10					c,b,a/b,a,a /b,b,a	85					N	A
11			N	A	c,b,a/b,a,a /b,b,a	85						
12	N	A	N	A	c,b,a/b,b,a /b,b,a	83					N	A
13	N		N	A	c,b,a/b,a,a /c,b,a	81					N	A
14					b,a,a/b,b,a /b,b,a	90						
15					b,a,a/b,a,a /b,b,a	92					N	A
16					b,a,a/b,a,a /b,b,a	92						
17	N	A	N	A	b,a,a/b,b,a /b,b,a	90					N	A
18	N	A	N	A	b,a,a/b,a,a /c,b,a	88					N	A

Attribute Data ↑ ↑ Rating

N/A - Not a viable system/vessel combination

Definition and Values for L

(a) No chance (L = 0)

(b) Highly unlikely (L = 1)

(c) Fair to even chance (L = 2)

(d) Higly likely (L = 4)

Definition and Values for S

(a) No resultant injury (S = 1)

(b) Results in injury of low to moderate severity (requiring first aid or limited medical treatment) (S = 2)

(c) Results in severe injury or death (S = 4)

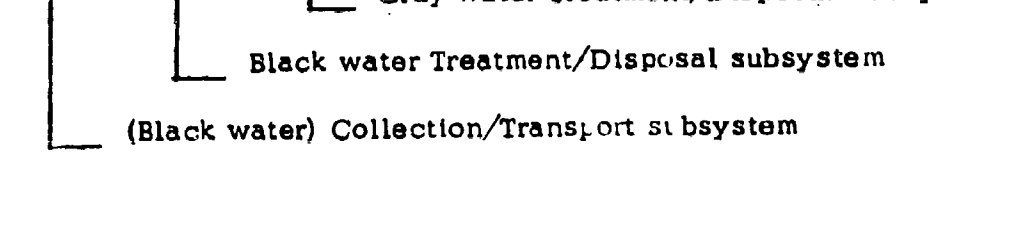
Definition and Values for C

(a) Hazardous situation can be easily corrected (C = 1)

(b) Hazardous situation is difficult to correct (C = 2)

(c) Hazardous situation cannot be corrected (C = 4)

WMS data (independent of vessel) is given in the form

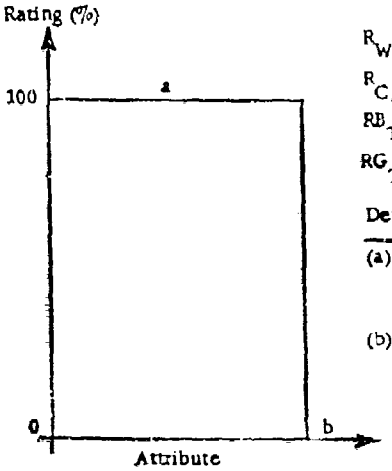


M/E V - HABITABILITY

11	Habitability problems* associated with bacterial contamination due to WMS inherent design

Effectiveness Rating Function

$R_{WMS} = \text{Min}\,(R_{C/T}, RB_{T/D}, RG_{T/D})$



R_{WMS} - Rating for WMS

$R_{C/T}$ - Rating for (black water) C/T subsystem

$RB_{T/D}$ - Rating for black water T/D subsystem

$RG_{T/D}$ - Rating for gray water T/D subsystem

Data given in the form (not vessel dependent):

$Z_{C/T}$, $ZB_{T/D}$, $ZG_{T/D}$ } Attribute

$R_{C/T}$, $RB_{T/D}$, $RG_{T/D}$ } Ratings

Definitions of $Z_{C/T}$, $ZB_{C/T}$, $ZG_{T/D}$

(a) There is no habitability problem associated with bacterial contamination as a result of WMS subsystem inherent design features.

(b) There is a habitability problem associated with bacterial contamination as a result of WMS subsystem inherent design features.

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
✓		

*As distinguished from problems of health and safety; likely psychological reactions of users are a matter for consideration.

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1					a/a/a	100						
2					a/b/a	0					N	A
3			N	A	a/b/a	0					N	A
4			N	A	a/b/a	0					N	A
5	N	A	N	A	a/b/b	0					N	A
6	N	A	N	A	a/a/b	0					N	A
7			N	A	a/b/a	0					N	A
8	N	A	N	A	a/b/b	0					N	A
9					a/a/a	100						
10					a/a/a	100					N	A
11			N	A	a/a/a	100						
12	N	A	N	A	a/a/b	0					N	A
13	N	A	N	A	a/a/b	0					N	A
14					a/a/a	100						
15					a/a/a	100					N	A
16					a/a/a	100						
17	N	A	N	A	a/a/b	0					N	A
18	N	A	N	A	a/a/b	0					N	A

Attribute Data — Rating

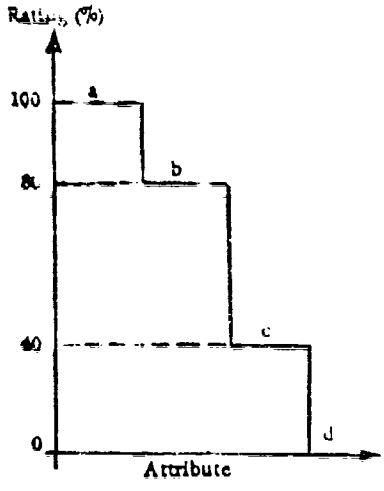
N/A - Not a viable system/vessel combination

M/E V - HABITABILITY

12	Habitability problems* associated with bacterial contamination due to procedural errors/equipment failures of WMS

Effectiveness Rating Function

$R_{WMS} = Min (R_{C/T}, RB_{T/D}, RG_{T/D})$



R_{WMS} - Rating for WMS

$R_{C/T}$ - Rating for (black water) C/T subsystem

$RB_{T/D}$ - Rating for black water T/D subsystem

$RG_{T/D}$ - Rating for gray water T/D subsystem

* As distinguished from problems of health and safety; likely psychological reactions of users are a matter for consideration.

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
✓		

(Continued)

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1					a/a/a	100						
2					b/b/a	80					N	A
3			N	A	b/b/a	80					N	A
4			N	A	b/b/a	80					N	A
5	N	A	N	A	b/b/b	80					N	A
6	N	A	N	A	a/a/b	80					N	A
7			N	A	b/b/a	80					N	A
8	N	A	N	A	b/b/a	80					N	A
9					a/a/a	100						
10					a/a/a	100					N	A
11			N	A	a/a/a	100						
12	N	A	N	A	a/a/b	80					N	A
13	N	A	N	A	a/a/b	80					N	A
14					b/a/a	80						
15					b/a/b	80					N	A
16					b/a/a	80						
17	N	A	N	A	b/a/b	80					N	A
18	N	A	N	A	b/a/b	80					N	A

Attribute Data ↑ ↑ Rating

N/A - Not a viable system/vessel combination

Data given in the form (not vessel dependent):

$Z_{C/T}$, $ZB_{T/D}$, $ZG_{T/D}$ } Attribute

$R_{C/T}$, $RB_{T/D}$, $RG_{T/D}$ } Ratings

Definitions of $Z_{C/T}$, $ZB_{T/D}$, $ZG_{T/D}$

(a) A bacterial contamination problem due to procedural errors/equipment failures of WMS subsystem is highly unlikely.

(b) Procedural errors/equipment failures of WMS subsystem are likely to cause a bacterial contamination problem.

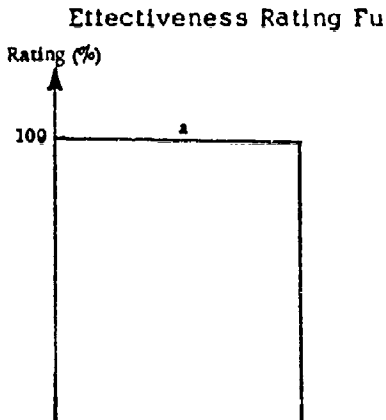
NOTE: The JERED MSD, because it has a vacuum collection system, is less likely to expose personnel to sewage in case of a line break; the Chrysler, however, will not only expose personnel to sewage but also to bacteria-contaminated oil; the GATX is more likely to expose personnel to bacterial contamination due to its pressurized sewer lines.

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E V - HABITABILITY

21	WMS fixture comfort

Effectiveness Rating Function



(a) Commodes and urinals are comfortable and easy to use, even under ship's motion.

(b) Commodes and urinals are not comfortable and not easy to use under ship's motion.

Data not vessel dependent.

Source of Data		
NSD Anal.	WMS Install. Anal.	WMS Con. Anal.
✓		

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1					a	100						
2					a	100					N	A
3			N	A	a	100					N	A
4			N	A	a	100					N	A
5	N	A	N	A	a	100					N	A
6	N	A	N	A	a	100					N	A
7			N	A	a	100					N	A
8	N	A	N	A	a	100					N	A
9					a	100						
10					a	100					N	A
11			N	A	a	100						
12	N	A	N	A	a	100					N	A
13	N	A	N	A	a	100					N	A
14					a	100						
15					a	100					N	A
16					a	100						
17	N	A	N	A	a	100					N	A
18	N	A	N	A	a	100					N	A

Attribute Data — Rating

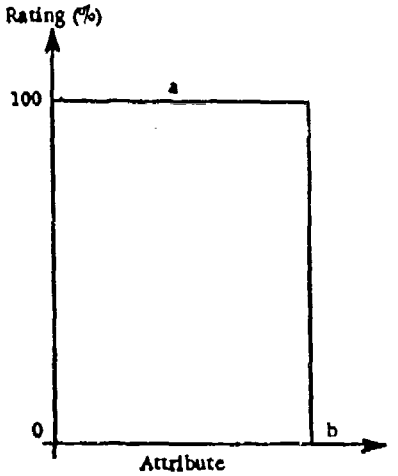
N/A - Not a viable system/vessel combination

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E _____ V - HABITABILITY

22	Flushing procedure requirements for WMS fixtures

Effectiveness Rating Function



(a) There are no "non-standard" requirements for flushing.

(b) There are "non-standard" requirements for flushing.

Data not vessel dependent.

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
✓		

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1					a	100						
2					a	100					N	A
3			N	A	a	100					N	A
4			N	A	a	100					N	A
5	N	A	N	A	a	100					N	A
6	N	A	N	A	a	100					N	A
7			N	A	a	100					N	A
8	N	A	N	A	a	100					N	A
9					b	0						
10					b	0					N	A
11			N	A	b	0						
12	N	A	N	A	b	0					N	A
13	N	A	N	A	b	0					N	A
14					b	0						
15					b	0					N	A
16					b	0						
17	N	A	N	A	b	0					N	A
18	N	A	N	A	b	0					N	A

Attribute Data ↑ ↑ Rating

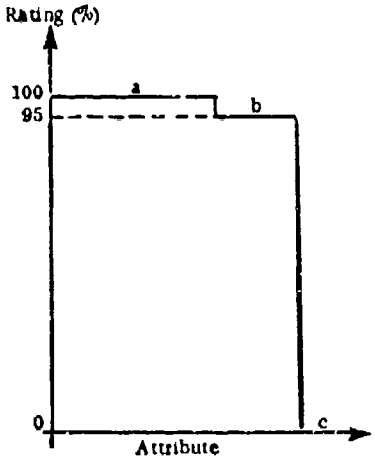
N/A - Not a viable system/vessel combination

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E V - HABITABILITY

23	Waste Retention in WMS commode bowl

Effectiveness Rating Function



(a) The amount of waste that remains in the bowl after flushing is less than that remaining after flushing a standard full volume water flushed fixture.

(b) The amount of waste that remains in the bowl after flushing is the same as that remaining after flushing a standard full volume water flushed fixture.

(c) The amount of waste that remains in the bowl after flushing is more than that remaining after flushing a standard full volume water flushed fixture.

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
✓		

Data not vessel dependent.

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1					b	95						
2					b	95					N	A
3			N	A	b	95					N	A
4			N	A	b	95					N	A
5	N	A	N	A	b	95					N	A
6	N	A	N	A	b	95					N	A
7			N	A	b	95					N	A
8	N	A	N	A	b	95					N	A
9					b	95						
10					b	95					N	A
11			N	A	b	95						
12	N	A	N	A	b	95					N	A
13	N	A	N	A	b	95					N	A
14					c	0						
15					c	0					N	A
16					c	0						
17	N	A	N	A	c	0					N	A
18	N	A	N	A	c	0					N	A

Attribute Data ↑ ↑ Rating

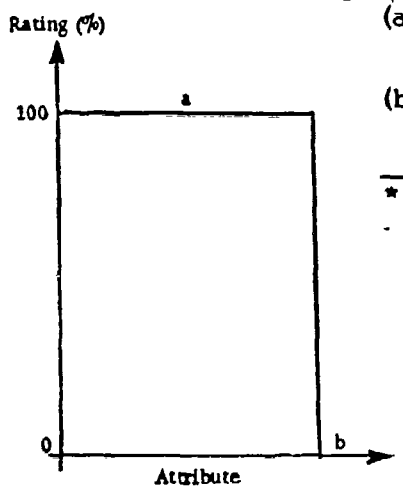
N/A - Not a viable system/vessel combination

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E V - HABITABILITY

24	Likelihood of user contact* with WMS fixture flushing medium

Effectiveness Rating Function



(a) User is unlikely to come into contact with flushing medium.

(b) User is more likely to come into contact with flushing medium than with standard water flushed fixture.

* Due to flushing medium composition or fixture design, motion of vessel (which may cause splatter, splashing, or spillage of flushing medium) WMS concept implementation, equipment failures, or operator errors. Systems which employ a pressurized sewer line (GATX) or oil return line (Chrysler) are more likely to expose personnel to fixture flushing medium or sewage in case of a line break.

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
✓		

Data vessel not dependent.

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1					a	100						
2					b	0					N	A
3			N	A	b	0					N	A
4			N	A	a	100					N	A
5	N	A	N	A	a	100					N	A
6	N	A	N	A	a	100					N	A
7			N	A	a	100					N	A
8	N	A	N	A	a	100					N	A
9					a	100						
10					a	100					N	A
11			N	A	a	100						
12	N	A	N	A	a	100					N	A
13	N	A	N	A	a	100					N	A
14					b	0						
15					b	0					N	A
16					b	0						
17	N	A	N	A	b	0					N	A
18	N	A	N	A	b	0					N	A

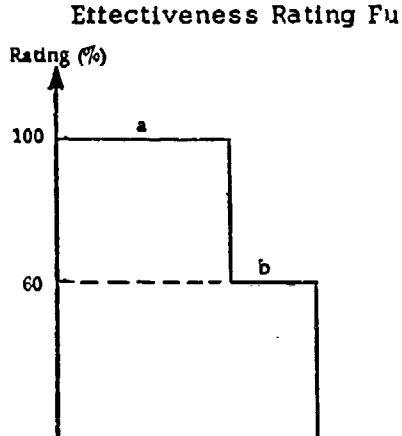
Attribute Data → ← Rating

N/A - Not a viable system/vessel combination

M/E V - HABITABILITY

25	Appearance of WMS fixture flushing medium

Effectiveness Rating Function



(a) The color and general appearance of the flushing medium are as acceptable as clear water.

(b) The color and general appearance of the flushing medium are acceptable, but clear water is preferable.

(c) The color and general appearance of the flushing medium are not acceptable.

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Con Anal.
✓		

Data not vessel dependent.

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1					a	100						
2					b	60					N	A
3			N	A	b	60					N	A
4			N	A	a	100					N	A
5	N	A	N	A	a	100					N	A
6	N	A	N	A	a	100					N	A
7			N	A	a	100					N	A
8	N	A	N	A	a	100					N	A
9					a	100						
10					a	100					N	A
11			N	A	a	100						
12	N	A	N	A	a	100					N	A
13	N	A	N	A	a	100					N	A
14					a	100						
15					a	100					N	A
16					a	100						
17	N	A	N	A	a	100					N	A
18	N	A	N	A	a	100					N	A

Attribute Data ↑ ↑ Rating

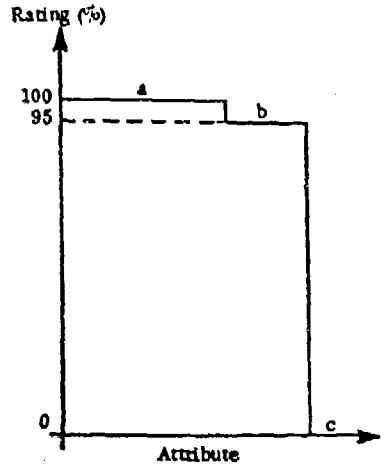
N/A - Not a viable system/vessel combination

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E V - HABITABILITY

26	Noise produced in flushing WMS fixtures

Effectiveness Rating Function



(a) The noise produced in flushing is less than that of a standard commode/urinal.

(b) The noise produced in flushing fixtures is the same as that of a standard commode/ urinal.

(c) The noise produced in flushing fixture is greater than that of a standard commode/ urinal.

Data not vessel dependent.

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
✓		

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1					b	95						
2					b	95					N	A
3			N	A	b	95					N	A
4			N	A	b	95					N	A
5	N	A	N	A	b	95					N	A
6	N	A	N	A	b	95					N	A
7			N	A	b	95					N	A
8	N	A	N	A	b	95					N	A
9					c	0						
10					c	0					N	A
11			N	A	c	0						
12	N	A	N	A	c	0					N	A
13	N	A	N	A	c	0					N	A
14					b	95						
15					b	95					N	A
16					b	95						
17	N	A	N	A	b	95					N	A
18	N	A	N	A	b	95					N	A

Attribute Data ↑ ↑ Rating

N/A - Not a viable system/vessel combination

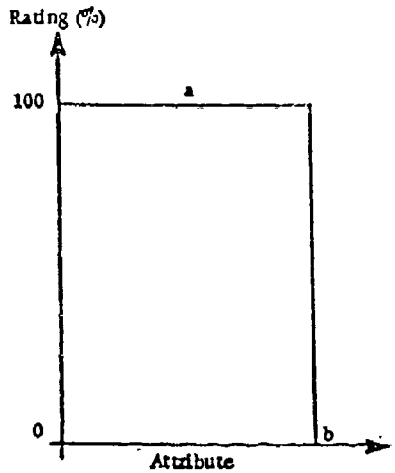
EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E — V - HABITABILITY

31 | Odors produced as a result of inherent WMS design

Effectiveness Rating Function

$$R_{WMS} = \text{Min}\,(R_{C/T}, RB_{T/D}, RG_{T/D})$$



R_{WMS} - Rating for WMS

$R_{C/T}$ - Rating for (black water) C/T subsystem

$RB_{T/D}$ - Rating for black water T/D subsystem

$RG_{T/D}$ - Rating for gray water T/D subsystem

Data given in the form (not vessel dependent):

$$\left.\begin{matrix} Z_{C/T}, & ZB_{T/D}, & ZG_{T/D} \\ \updownarrow & \updownarrow & \updownarrow \\ R_{C/T} & RB_{T/D} & RG_{T/D} \end{matrix}\right\} \begin{matrix} \text{Attribute} \\ \text{Ratings} \end{matrix}$$

Definitions of $Z_{C/T}$, $ZB_{T/D}$, $ZG_{T/D}$

(a) The WMS subsystem produces no odor as a result of inherent design.

(b) The WMS subsystem produces a noticable odor as a result inherent design.

Source of Data		
NSD Anal.	WMS Install. Anal.	WMS Cost Anal.
✓		

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1					a/b/b	0						
2					a/b/b	0					N	A
3			N	A	a/b/b	0					N	A
4			N	A	a/a/b	0					N	A
5	N	A	N	A	a/a/a	100					N	A
6	N	A	N	A	a/b/a	0					N	A
7			N	A	a/a/b	0					N	A
8	N	A	N	A	a/a/a	100					N	A
9					a/b/b	0						
10					a/a/b	0					N	A
11			N	A	a/a/b	0						
12	N	A	N	A	a/b/a	0					N	A
13	N	A	N	A	a/a/a	100					N	A
14					a/b/b	0						
15					a/a/b	0					N	A
16					a/a/b	0						
17	N	A	N	A	a/b/a	0					N	A
18	N	A	N	A	a/a/a	100					N	A

Attribute Data ↑ ↑ Rating

N/A - Not a viable system/vessel combination

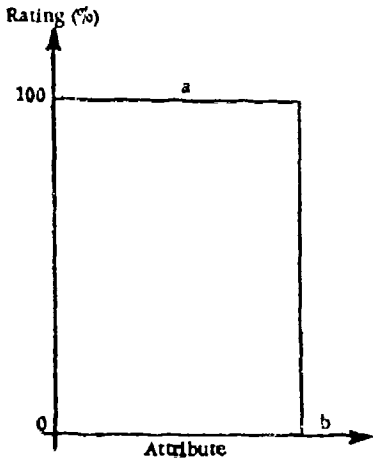
EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E V - HABITABILITY

32 Odors produced as a result of procedural errors/equipment failures of WMS

Effectiveness Rating Function

$$R_{WMS} = \text{Min}\,(R_{C/T}, RB_{T/D}, RG_{T/D})$$



R_{WMS} - Rating for WMS

$R_{C/T}$ - Rating for (black water) C/T subsystem

$RB_{T/D}$ - Rating for black water T/D subsystem

$RG_{T/D}$ - Rating for gray water T/D subsystem

Data given in the form (not vessel dependent):

$Z_{C/T}, ZB_{T/D}, ZG_{T/D}$ } Attribute

$R_{C/T}, RB_{T/D}, RG_{T/D}$ } Ratings

Definitions of $Z_{C/T}$, $ZB_{T/D}$, $ZG_{T/D}$

(a) The WMS subsystem produces no odor as a result of procedural errors equipment failures.

(b) The WMS subsystem produces a noticeable odor as a result of procedural errors/equipment failures.

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
✓		

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1					b/b/b	0						
2					b/b/b	0					N	A
3			N	A	b/b/b	0					N	A
4			N	A	b/b/b	0					N	A
5	N	A	N	A	b/b/b	0					N	A
6	N	A	N	A	b/b/b	0					N	A
7			N	A	b/b/b	0					N	A
8	N	A	N	A	b/b/b	0					N	A
9					b/b/b	0						
10					b/b/b	0					N	A
11			N	A	b/b/b	0						
12	N	A	N	A	b/b/b	0					N	A
13	N	A	N	A	b/b/b	0					N	A
14					b/b/b	0						
15					b/b/b	0					N	A
16					b/b/b	0						
17	N	A	N	A	b/b/b	0					N	A
18	N	A	N	A	b/b/b	0					N	A

Attribute Data — Rating

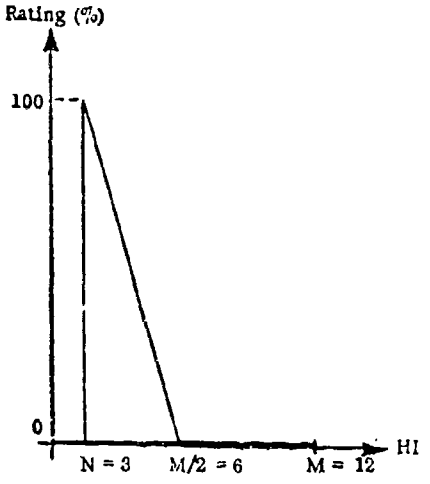
N/A - Not a viable system/vessel combination

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E V - HABITABILITY

41 Heat generation for nearby personnel* due to inherent design.

Effectiveness Rating Function



$$R_{iv}(\%) = 100 - \frac{100}{3}(HF - 3) \quad 3 \le HF \le 6$$
$$= 0 \quad 6 < HF \le 12$$

$HF = I \times HI$

$HI = HI_{C/T} + HIB_{T/D} + HIG_{T/D}$

$R_{iv}(\%)$ - Rating (%) of ith viable candidate WMS on vessel v

HF - Heat factor for nearby personnel due to inherent WMS design and installation

I - Installation index (for heat)

HI - Heat index for WMS

$HI_{C/T}$ - Heat index for (black water) Collection/Transport subsystem

$HIB_{T/D}$ - Heat index for black water Treatment/Disposal subsystem

$HIG_{T/D}$ - Heat index for gray water Treatment/Disposal subsystem

M - Maximum possible value of HF = 2 (2 + 2+ 2) = 12

N - Minimum value of HF = 1(1 + 1 + 1) = 3

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
✓	✓	

* For operator/maintainer/adjacent berthing and working areas.

(Continued)

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	a/	100	a/	100	a/a/a/a	100	a/	100	a/	100	a/	100
2	a/	100	a/	100	a/a/a/a	100	a/	100	a/	100	N	A
3	b/	0	N	A	a/a/b/a	67	b/	0	b/	0	N	A
4	a/	100	N	A	a/a/a/a	100	a/	100	a/	100	N	A
5	N	A	N	A	a/a/a/a	100	a/	100	a/	100	N	A
6	N	A	N	A	a/a/a/a	100	a/	100	a/	100	N	A
7	b/	0	N	A	a/a/b/a	67	b/	0	b/	0	N	A
8	N	A	N	A	a/a/b/b	33	b/	0	b/	0	N	A
9	a/	100	a/	100	a/a/a/a	100	a/	100	a/	100	a/	100
10	b/	0	b/	0	a/a/b/a	67	b/	0	b/	0	N	A
11	a/	100	N	A	a/a/a/a	100	a/	100	a/	100		
12	N	A	N	A	a/a/a/a	100	a/	100	a/	100	N	A
13	N	A	N	A	a/a/b/b	33	b/	0	b/	0	N	A
14	a/	100	a/	100	a/a/a/a	100	a/	100	a/	100	a/	100
15	b/	0	b/	0	a/a/b/a	67	b/	0	b/	0	N	A
16	a/	100	a/	100	a/a/a/a	100	a/	100	a/	100	a/	100
17	N	A	N	A	a/a/a/a	100	a/	100	a/	100	N	A
18	N	A	N	A	a/a/b/b	33	b/	0	b/	0	N	A

Attribute Data ↑ ↑ Rating

N/A - Not a viable system/vessel combination

Definition and values for I

(a) Location of WMS is not likely to raise heat level due to proximity to working and berthing areas (I = 1).

(b) Location of WMS is like to raise heat level due to proximity to working and berthing areas (I = 2).

Definition and values for $HI_{C/T}$, $HIB_{T/D}$, $HIG_{T/D}$

(a) The WMS subsystem does not generate enough heat, as a result of inherent design features to render its vicinity hotter than most shipboard areas containing machinery ($HI_{C/T}$, $HIB_{T/D}$ $HIG_{T/D}$ = 1).

(b) The WMS subsystem does generate enough heat, as a result of inherent design features to render its vicinity hotter than most shipboard areas containing machinery ($HI_{C/T}$, $HIB_{T/D}$, $HIB_{T/D}$ = 2).

WMS/vessel data is given in the form:

$I/\underbrace{HI_{C/T}, HIB_{T/D}, HIG_{T/D}}$

Not vessel dependent

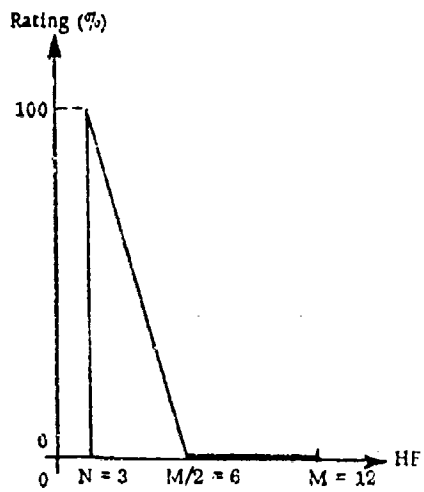
Vessel dependent

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E V - HABITABILITY

42	Heat generation for nearby personnel*due to procedural errors/equipment failures of WMS

Effectiveness Rating Function



$$R_{1v}(\%) = 100 - \frac{100}{3}(HF - 3) \quad 3 \le HF \le 6$$
$$= 0 \quad 6 < HF \le 12$$

$HF = I \times HI$

$HI = HI_{C/T} + HIB_{T/D} + HIG_{T/D}$

$R_{1v}(\%)$ - Rating (%) of ith viable candidate WMS on vessel v

HF - Heat factor for nearby personnel due to procedural errors/equipment failures of WMS and installation

I - Installation index for WMS

HI - Heat index for WMS

$HI_{C/T}$ - Heat index for (black water) Collection/Transport subsystem

$HIB_{T/D}$ - Heat index for black water Treatment/Disposal subsystem

$HIG_{T/D}$ - Heat index for gray water Treatment/Disposal subsystem

M - Maximum possible value of HF = 2 (2 + 2 + 2) = 12

N - Minimum value of HF = 1(1 + 1 + 1) = 3

* For operator/maintainer/adjacent berthing and working areas.

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
✓	✓	

(Continued)

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	a/	100	a/	100	a/a,a,a	100	a/	100	a/	100	a/	100
2	a/	100	a/	100	a/a,a,a	100	a/	100	a/	100	N	A
3	b/	0	N	A	a/a,b,a	67	b/	0	b/	0	N	A
4	a/	100	N	A	a/a,a,a	100	a/	100	a/	100	N	A
5	N	A	N	A	a/a,a,a	100	a/	100	a/	100	N	A
6	N	A	N	A	a/a,a,a	100	a/	100	a/	100	N	A
7	b/	0	N	A	a/a,b,a	67	b/	0	b/	0	N	A
8	N	A	N	A	a/a,b,b	33	b/	0	b/	0	N	A
9	a/	100	a/	100	a/a,a,a	100	a/	100	a/	100	a/	100
10	b/	0	b/	0	a/a,b	67	b/	0	b/	0	N	A
11	a/	100	N	A	a/a,a,a	100	a/	100	a/	100	a/	100
12	N	A	N	A	a/a,a,a	100	a/	100	a/	100	N	A
13	N	A	N	A	a/a,b,b	33	b/	0	b/	0	N	A
14	a/	100	a/	100	a/a,a,a	100	a/	100	a/	100	a/	100
15	b/	0	b/	0	a/a,b,a	67	b/	0	b/	0	N	A
16	a/	100	a/	100	a,a,a,a	100	a/	100	a/	100	a/	100
17	N	A	N	A	a/a,a,a	100	a/	100	a/	100	N	A
18	N	A	N	A	a/a,b,b	33	b/	0	b/	0	N	A

Attribute Data → ← Rating

N/A - Not a viable system/vessel combination

Definition and values for I

(a) Location of WMS is not likely to raise heat level due to proximity to working and berthing areas (I = 1).

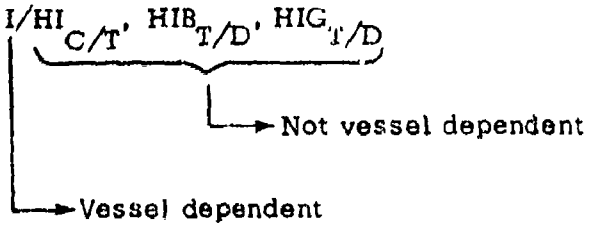
(b) Location of WMS is like to raise heat level due to proximity to working and berthing areas (I = 2).

Definition and values for $HI_{C/T}$, $HIB_{T/D}$, $HIG_{T/D}$

(a) The WMS subsystem does not generate enough heat, as a result of procedural errors/equipment failures, to render its vicinity hotter than most shipboard areas containing machinery ($HI_{C/T}$, $HIB_{T/D}$, $HIG_{T/D}$ = 1).

(b) The WMS subsystem does generate enough heat, as a result of procedural errors/equipment failures, to render its vicinity hotter than most shipboard areas containing machinery ($HI_{C/T}$, $HIB_{T/D}$, $HIB_{T/D}$ = 2).

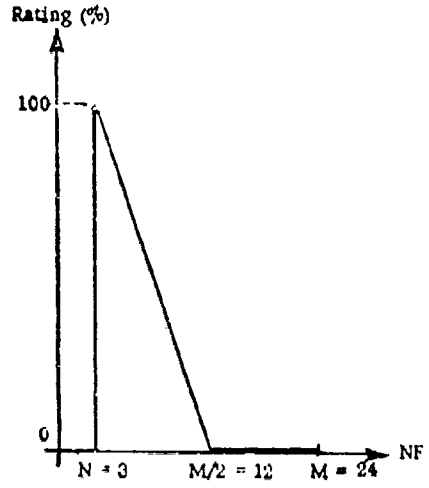
WMS/vessel data is given in the form:



M/E _____ V - HABITABILITY

5	Noise level for personnel* in vicinity of WMS

Effectiveness Rating Function



$NF = I \times NI$

$NI = NI_{C/T} + NIB_{T/D} + NIG_{T/D}$

$R_{Iv}(\%) = 100 - \frac{100}{c}(NF - 3)$ for $3 \le NF \le 12$

$= 0$ for $12 < NF \le 24$

$R_{Iv}(\%)$ - Rating (%) of Ith viable candidate WMS on vessel v

NF - Noise factor for nearby personnel due to WMS and installation

I - Installation index (for noise)

NI - Noise index for WMS

$NI_{C/T}$ - Noise index for (black water) Collection/Transport subsystem

$NIB_{T/D}$ - Noise index for black water Treatment/Disposal subsystem

$NIG_{T/D}$ - Noise index for gray water Treatment/Disposal subsystem

M - Maximum possible value of NF = 2 (4 + 4 + 4) = 24

N - Maximum value of NF = 1(1 + 1 + 1) = 3

* For operator/maintainer/adjacent working and berthing areas.

Source of Data		
NSEP Anal.	WMS Install. Anal	WMS Cost Anal.
✓	✓	

(Continued)

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	a/	100	a/	100	a/ a, a,a	100	a/	100	a/	100	a/	100
2	a/	78	a/	78	a/ b,b,a	78	a/	78	a/	78	N	A
3	a/	78	N	A	a/ b,b,a	78	a/	78	a/	78	N	A
4	a/	78	N	A	a/ b,b,a	78	a/	78	a/	78	N	A
5	N	A	N	A	a/ b,b,b	67	a/	67	a/	67	N	A
6	N	A	N	A	a/ a,a,b	89	a/	89	a/	89	N	A
7	a/	78	N	A	a/ b,b,a	78	a/	78	a/	78	N	A
8	N	A	N	A	a/ b,b,b	67	a/	67	a/	67	N	A
9	a/	89	a/	89	a/ b,a,a	89	a/	89	a/	89	a/	89
10	a/	78	a/	78	a/ b,b,a	78	a/	78	a/	78	N	A
11	a/	78	N	A	a/ b,b,a	78	a/	78	a/	78	a/	78
12	N	A	N	A	a/ b,a,b	78	a/	78	a/	78	N	A
13	N	A	N	A	a/ b,b,b	67	a/	67	a/	67	N	A
14	a/	89	a/	89	a/ b,a,a	89	a/	89	a/	89	a/	89
15	a/	78	a/	78	a/ b,b,a	78	a/	78	a/	78	N	A
16	a/	78	a/	78	a/ b,b,a	78	a/	78	a/	78	a/	78
17	N	A	N	A	a/ b,a,b	78	a/	78	a/	78	N	A
18	N	A	N	A	a/ b,b,b	67	a/	67	b/	0	N	A

Attribute Data ↑ ← Rating

N/A - Not a viable system/vessel combination

V-5

Definition and values for I

(a) Location of WMS is not likely to raise noise level due to proximity to working and berthing areas (I = 1)

(b) Location of WMS is likely to raise noise level due to proximity to working and berthing areas (I = 2)

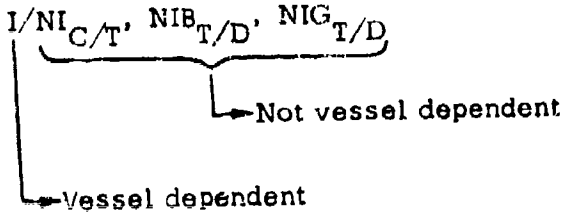
Definition and values for $NI_{C/T}$, $NIB_{T/D}$, $NIG_{T/D}$

(a) Subsystem is silent or nearby silent ($NI_{C/T}$, $NIB_{T/D}$, $NIG_{T/D}$ = 1)

(b) Noise level of subsystem is approximately equal to background noise level of vessel ($NI_{C/T}$, $NIB_{T/D}$, $NIG_{T/D}$ = 2)

(c) Subsystem is very loud, produces constant noise, drowns out vessel background noise in immediate area of the system; must shout to be heard ($NI_{C/T}$, $NIB_{T/D}$, $NIG_{T/D}$ = 4)

WMS/vessel data is given in the form:

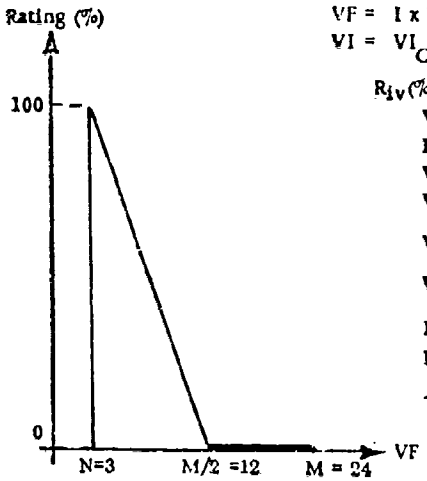


EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E _____ V - HABITABILITY

6 Vibration levels for nearby personnel* produced by WMS machinery

Effectiveness Rating Function



$$R_{iv}(\%) = 100 - \frac{100}{9}(VF - 3) \quad 3 \le VF \le 12$$
$$= 0 \quad 12 < VF \le 24$$

$VF = I \times VI$

$VI = VI_{C/T} + VIB_{T/D} + VIG_{T/D}$

$R_{iv}(\%)$ - Rating(%) of ith viable candidate WMS on vessel v

VF - Vibration factor for nearby personnel due to WMS and installation

I - Installation index (for vibration)

VI - Vibration index for WMS

$VI_{C/T}$ - Vibration index for (black water) Collection/Transport subsystem

$VIB_{T/D}$ - Vibration index for black water Treatment/Disposal subsystem

$VIG_{T/D}$ - Vibration index for gray water Treatment/Disposal subsystem

M - Maximum possible value of VF = 2 (4 + 4 + 4) = 24

N - Minimum value of VF = 1(1 + 1 + 1) = 3

* For operator/maintainer/adjacent working and berthing areas.

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
✓	✓	

(Continued)

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	a/	100	a/	100	a/a, a, a	100	a/	100	a/	100	a/	100
2	a/	100	a/	100	a/a, a, a	100	a/	100	a/	100	N	A
3	a/	100	N	A	a/a, a, a	100	a/	100	a/	100	N	A
4	a/	89	N	A	a/a, b, a	89	a/	89	a/	89	N	A
5	N	A	N	A	a/a, b, b	78	a/	78	a/	78	N	A
6	N	A	N	A	a/a, a, b	89	a/	89	a/	89	N	A
7	a/	89	N	A	a/a, b, a	89	a/	89	a/	89	N	A
8	N	A	N	A	a/a, b, b	78	a/	78	a/	78	N	A
9	a/	100	a/	100	a/a, a, a	100	a/	100	a/	100	a/	100
10	a/	100	a/	100	a/a, a, a	100	a/	100	a/	100	N	A
11	a/	100	N	A	a/a, a, a	100	a/	100	a/	100	a/	100
12	N	A	N	A	a/a, a, b	89	a/	89	a/	89	N	A
13	N	A	N	A	a/a, a, b	89	a/	89	a/	89	N	A
14	a/	100	a/	100	a/a, a, a	100	a/	100	a/	100	a/	100
15	a/	100	a/	100	a/a, a, a	100	a/	100	a/	100	N	A
16	a/	100	a/	100	a/a, a, a	100	a/	100	a/	100	a/	100
17	N	A	N	A	a/a, a, b	89	a/	89	a/	89	N	A
18	N	A	N	A	a/a, a, b	89	a/	89	b/	44	N	A

Attribute Data ↑ ↑ Rating

N/A - Not a viable system/vessel combination

Definition and values for I

(a) Location of WMS is not likely to raise vibration level due to proximity to working and berthing areas (I = 1)

(b) Location of WMS is likely to raise vibration level due to proximity to working and berthing areas (I = 2)

Definitions and values for $VI_{C/T}$, $VIB_{T/D}$, $VIG_{T/D}$

(a) WMS subsystem produces little or no perceptible vibration in addition to background level on vessel ($VI_{C/T}$, $VIB_{T/D}$, $VIG_{T/D}$ = 1).

(b) WMS subsystem produces perceptible vibration, but similar to vessel background ($VI_{C/T}$, $VIB_{T/D}$, $VIG_{T/D}$ = 2).

(c) WMS subsystem produces abnormal & disturbing intensity and/or frequency of vibration ($VI_{C/T}$, $VIB_{T/D}$, $VIG_{T/D}$ = 4).

WMS/vessel data is given in the form :

$I/VI_{C/T}$, $VIB_{T/D}$, $VIG_{T/D}$

$VI_{C/T}$, $VIB_{T/D}$, $VIG_{T/D}$ → Not vessel dependent

I → Vessel dependent

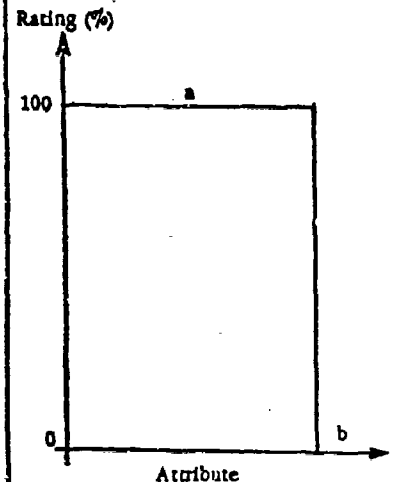
EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E ____ V - HABITABILITY

7	Effect of WMS on user housekeeping routines

Effectiveness Rating Function

$$R_{WMS} = \text{Min}\,(R_{C/T},\ RB_{T/D},\ RG_{T/D})$$



R_{WMS} - Rating for WMS

$R_{C/T}$ - Rating for (black water) C/T subsystem

$RB_{T/D}$ - Rating for black water T/D subsystem

$RG_{T/D}$ - Rating for gray water T/D subsystem

Data given in the form (not vessel dependent):

$Z_{C/T}$, $ZB_{T/D}$, $ZG_{T/D}$ } Attribute

$R_{C/T}$, $RB_{T/D}$, $RG_{T/D}$ } Ratings

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
✓		

(Continued)

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1					a, a, a	100						
2					b, b, a	0					N	A
3			N	A	b, b, a	0					N	A
4			N	A	a, a, a	100					N	A
5	N	A	N	A	a, a, a	100					N	A
6	N	A	N	A	a, a, a	100					N	A
7			N	A	a, a, a	100					N	A
8	N	A	N	A	a, a, a	100					N	A
9					a, a, a	100						
10					a, a, a	100					N	A
11			N	A	a, b, a	0						
12	N	A	N	A	a, a, a	100					N	A
13	N	A	N	A	a, a, a	100					N	A
14					a, a, a	100						
15					a, a, a	100					N	A
16					a, b, a	0						
17	N	A	N	A	a, a, a	100					N	A
18	N	A	N	A	a, a, a	100					N	A

Attribute Data ↑ ↑ Rating

N/A = Not a viable system/vessel combination

Definitions of $Z_{C/T}$, $ZB_{T/D}$, $ZG_{T/D}$

(a) WMS subsystem characteristics have no effect on user housekeeping routines. Applies to CHT, JERED, and Grumman. (If a very large amount of detergent is deposited in the CHT, some foaming may result.)

(b) WMS subsystem characteristics have an effect on user housekeeping routines. Applies to the Chrysler and GATX MSDs.

NOTES: 1. Detergent should not be dumped into fixtures associated with the Chrysler C/T and T/D subsystems.

2. Detergent is very likely to cause foaming in evaporator.

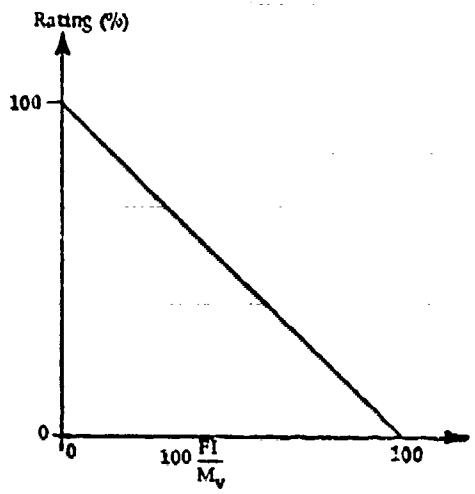
EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E VI - RELIABILITY

1	Failure frequency index for WMS (relative)

Effectiveness Rating Function

$$R_{iv}(\%) = 100 - 100\,\frac{FI_i}{M_v} \qquad 0 \le \frac{FI_i}{M_v} \le 1.0$$



$R_{iv}(\%)$ - Rating (%) of ith viable candidate WMS on vessel v

FI_i - Failure frequency index of ith viable WMS candidate on vessel v. FI_i is the estimated number of failures based on projected WMS utilization

M_v - Maximum value of FI_i for all viable WMS candidates on a given vessel v

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Con Anal.
		✓

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	22	96	24	94	10	96	16	84	10	91	5	89
2	68	88	30	92	20	93	26	74	24	78	N	A
3	74	87	N	A	21	93	26	74	24	78	N	A
4	44	92	N	A	18	94	27	73	15	86	N	A
5	N	A	N	A	23	92	24	76	14	87	N	A
6	N	A	N	A	23	92	24	76	15	86	N	A
7	44	92	N	A	18	94	27	73	16	86	N	A
8	N	A	N	A	26	91	24	76	12	89	N	A
9	547	3	396	1	259	8	83	17	105	5	47	0
10	(562)	0	(399)	0	(280)	0	(100)	0	(111)	0	N	A
11	562	0	N	A	264	6	86	14	106	5	(47)	0
12	N	A	N	A	271	3	96	4	109	2	N	A
13	N	A	N	A	268	4	93	7	109	2	N	A
14	197	65	110	72	46	84	39	61	61	45	18	62
15	203	64	119	70	66	76	56	44	67	40	N	A
16	212	62	113	72	51	82	42	58	62	44	18	62
17	N	A	N	A	58	79	52	48	65	41	N	A
18	N	A	N	A	55	80	49	51	65	41	N	A

Attribute Data ↑ ↑ Rating

N/A - Not a viable system/vessel combination

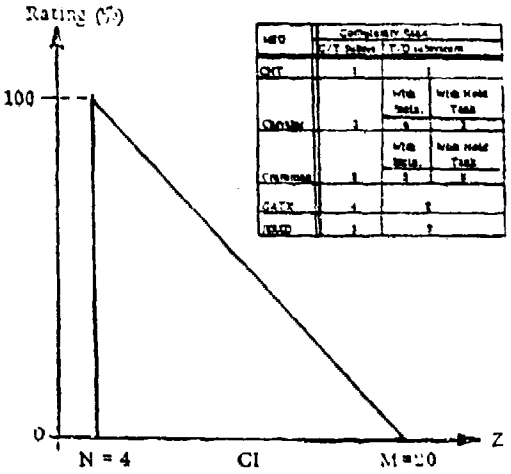
EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E VI - RELIABILITY

21	WMS complexity

Effectiveness Rating Function

$$R_i(\%) = 100 - \frac{100}{16}(CI - 4) \qquad 4 \leq CI \leq 20$$



MSD	Complexity Table		
	C/T Subsys	T/D subsystem	
CHT	1	1	
Chrysler	1	With Insta. 6	With Hold Tank 3
Grumman	1	With Insta. 5	With Hold Tank 5
GATX	4	2	
[illegible]	1	2	

$CI = 2\,CI_{C/T} + CIB_{T/D} + CIG_{T/D}$

$R_i(\%)$ - Rating (%) viable candidate WMS (independent of vessel)

CI - Complexity index of ith viable candidate (independent of vessel)

$CI_{C/T}$ - Complexity index of WMS (black water) Collection/ Transport subsystem based on a complexity ranking.

$CIB_{T/D}$ - Complexity index of WMS black water Treatment/ Disposal subsystem based on a complexity ranking.

$CIG_{T/D}$ - Complexity index of WMS gray water Treatment/ Disposal subsystem based on a complexity ranking.

M - Maximum value of CI for any WMS (independent vessel) = 2 (5) + 5 + 5 = 20

N - Minimum value of CI = 2 + 1 + 1 = 4

Data given in the form (not vessel dependent): $CI_{C/T}$, $CIB_{T/D}$, $CIG_{T/D}$

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
✓		

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1					1, 1, 1	100						
2					3, 3, 1	63					N	A
3			N	A	3, 4, 1	56					N	A
4			N	A	2, 5, 1	63					N	A
5	N	A	N	A	2, 5, 5	38					N	A
6	N	A	N	A	1, 1, 5	75					N	A
7			N	A	2, 5, 1	63					N	A
8	N	A	N	A	2, 5, 5	38					N	A
9					5, 1, 1	50						
10					5, 3, 1	38					N	A
11			N	A	5, 2, 1	44						
12	N	A	N	A	5, 1, 5	25					N	A
13	N	A	N	A	5, 5, 5	0					N	A
14					4, 1, 1	63						
15					4, 3, 1	50					N	A
16					4, 2, 1	56						
17	N	A	N	A	4, 1, 5	38					N	A
18	N	A	N	A	4, 5, 5	13					N	A

Attribute Data ↑ ↑ Rating

N/A - Not a viable system/vessel combination

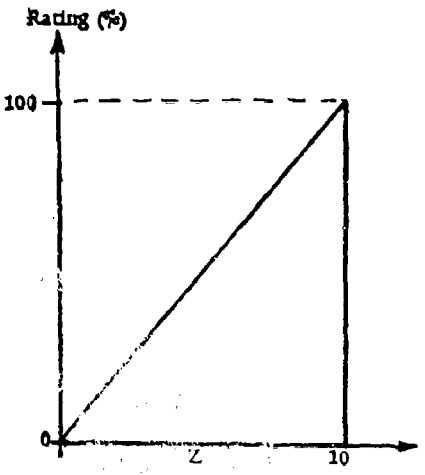
EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E ____ VI - RELIABILITY

22	Extent of WMS configuration redundancy

Effectiveness Rating Function

$R_{IV}(\%) = 10\,Z$; $0 \le Z \le 10$



$$Z = 5\,Z_C \times Z_T + 3\,ZB_{T/D} + 2\,ZG_{T/D}$$

$R_{IV}(\%)$ - Rating (%) of ith viable candidate WMS on vessel v

Z - Configuration redundancy index for WMS

Z_C - Configuration redundancy index for (black water) waste Collection portion of WMS (i.e., more than one commode)

Z_T - Configuration redundancy index for (black water) waste Transport portion of WMS

$ZB_{T/D}$ - Configuration redundancy index for WMS black water T/D subsystem

$ZG_{T/D}$ - Configuration redundancy index for WMS gray water T/D subsystem

M - Maximum possible value of $Z = 5(1) + 3(1) + 2(1) = 10$

(Continued)

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
	✓	

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	a, a/a/a	100	a, a/a/a	100	a, a/a/a	100	a, a/a/a	100	a, a/a/a	100	a, a/a/b	80
2	a, a/a/a	100	a, b/b/a	20	a, b/b/b	0	a, b/b/a	20	a, b/b/a	20	N	A
3	a, a/a/a	100	N	A	a, b/b/a	20	a, b/b/a	20	a, b/b/a	20	N	A
4	a, a/a/a	100	N	A	a, a/b/a	70	a, a/b/a	70	a, a/b/a	70	N	A
5	N	A	N	A	a, a/a/a	100	a, a/b/b	50	a, a/b/b	50	N	A
6	N	A	N	A	a, a/a/a	100	a, a/a/b	80	a, a/a/b	80	N	A
7	a, a/a/a	100	N	A	a, a/b/a	70	a, a/b/a	70	a, a/b/a	70	N	A
8	N	A	N	A	a, a/a/a	100	a, a/b/b	50	a, a/b/b	50	N	A
9	a, a/a/a	100	a, a/a/a	100	a, a/a/a	100	a, b/a/a	50	a, b/a/a	50	a, b/a/a	50
10	a, a/a/a	100	a, a/b/a	70	a, a/b/a	70	a, b/b/a	20	a, b/b/a	20	N	A
11	a, a/a/a	100	N	A	a, a/a/a	100	a, b/b/a	20	a, b/b/a	20	a, b/b/a	20
12	N	A	N	A	a, a/a/a	100	a, b/a/b	30	a, b/b/b	0	N	A
13	N	A	N	A	a, a/a/b	80	a, b/b/b	0	a, b/b/b	0	N	A
14	a, a/a/a	100	a, a/a/a	100	a, a/a/a	100	a, a/a/a	100	a, a/a/a	100	a, a/a/a	100
15	a, a/b/a	70	a, a/b/a	70	a, a/b/a	70	a, a/b/a	70	a, a/b/a	70	N	A
16	a, a/a/a	100	a, a/a/a	100	a, a/a/a	100	a, a/b/a	70	a, a/b/a	70	a, a/b/a	70
17	N	A	N	A	a, a/a/a	100	a, a/a/b	80	a, a/a/b	80	N	A
18	N	A	N	A	a, a/a/b	80	a, a/b/b	50	a, a/b/b	50	N	A

Attribute Data ↑ ↑ Rating

N/A - Not a viable system/vessel combination

Data given in the form:

$$Z_C, Z_T/ZB_{T/D}/ZG_{T/D}$$

Definition and values for Z_C, Z_T, $ZB_{T/D}$, $ZG_{T/D}$

(a) There is configuration redundancy, i.e., failure of any one equipment will not result in the failure of the subsystem ($Z_C, Z_T, ZB_{T/D}, ZG_{T/D} = 1$).

(b) There is no configuration redundancy, i.e., failure of one equipment will result in the failure of the subsystem (also applies if no subsystem available, e.g., a holding tank with 0 capacity).
($Z_C, Z_T, ZB_{T/D}, ZG_{T/D} = 0$)

Note:

In determining subsystem redundancy, the following criteria were utilized:

Collection Subsystem

- All ships with two (2) or more commodes are considered to have collection subsystem redundancy.

Transport Subsystem

- All WMS with CHT or Grumman treatment/disposal are considered to have transport redundancy.
- All WMS with Chrysler collection are considered to have transport redundancy only if two or more Chrysler systems are specified (since failure of treatment subsystem result in unavailability of purified oil for flushing).
- All WMS with GATX collection are considered to be redundant only if two or more M/T pumps are specified.
- All WMS with JERED collection are considered to be redundant if one (1) or more large boat VCT's are specified (two pumps for each large boat VCT) or two (2) or more small boat VCT's are specified (one pump for each small boat VCT).

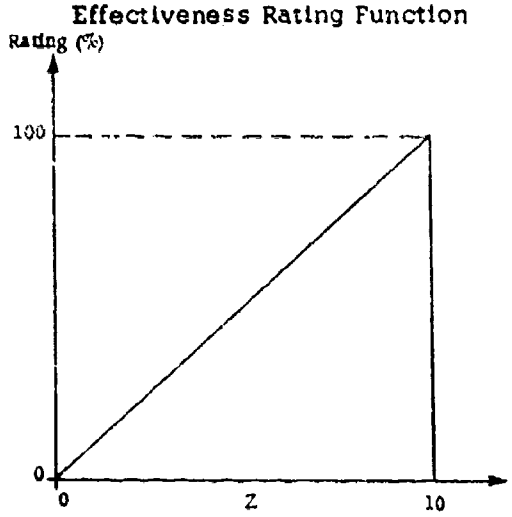
Treatment/Disposal Subsystem

- All WMS with CHT subsystem for black/gray water are considered to have redundant T/D subsystems.
- All WMS with Chrysler treatment subsystem for black water are considered to have redundant T/D subsystems only if two (2) or more Chrysler units are specified.
- All WMS GATX treatment subsystem black water are considered to have redundant T/D subsystems only if two (2) or more evaporators are specified.
- All WMS with Grumman treatment subsystem for black/gray water are considered to have redundant T/D subsystem only if two (2) or more Grumman units are specified.
- All WMS with JERED treatment subsystem for black water are considered to have redundant T/D subsystems only if two (2) or more incinerators are specified.

23	Extent of WMS equipment/component redundancy*

Effectiveness Rating Function

$R_i(\%) = 10Z \quad 0 \le Z \le 10$



$Z = 5Z_{C/T} + 3ZB_{T/D} + 2ZG_{T/D}$

$R_i(\%)$ - Rating (%) of ith viable candidate WMS (independent of vessel)

Z - Redundancy index for WMS

$Z_{C/T}$ - Redundancy index for WMS (black water) C/T subsystem

$ZB_{T/D}$ - Redundancy index for WMS black water T/D subsystem

$ZG_{T/D}$ - Redundancy index for WMS gray water T/D subsystem

(Continued)

* Any redundancy in electronic circuitry is not considered.

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
✓		

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1					a, a, a	100						
2					a, b, a	70					N	A
3			N	A	a, b, a	70					N	A
4			N	A	a, a, a	100					N	A
5	N	A	N	A	a, a, a	100					N	A
6	N	A	N	A	a, a, a	100					N	A
7			N	A	a, b, a	70					N	A
8	N	A	N	A	a, b, b	50					N	A
9					a, a, a	100						
10					a, b, a	70					N	A
11			N	A	a, a, a	100						
12	N	A	N	A	a, a, a	100					N	A
13	N	A	N	A	a, b, b	50					N	A
14					a, a, a	100						
15					a, b, a	70					N	A
16					a, a, a	100						
17	N	A	N	A	a, a, a	100					N	A
18	N	A	N	A	a, b, b	50					N	A

Attribute Data ↑ ↑ Rating

N/A = Not a viable system/vessel combination

Data given in the form (not vessel dependent):

$$Z_{C/T}\ ,\ ZB_{T/D}\ ,\ ZG_{T/D}$$

Definition and values for $Z_{C/T}$, $ZB_{T/D}$, $ZG_{T/D}$

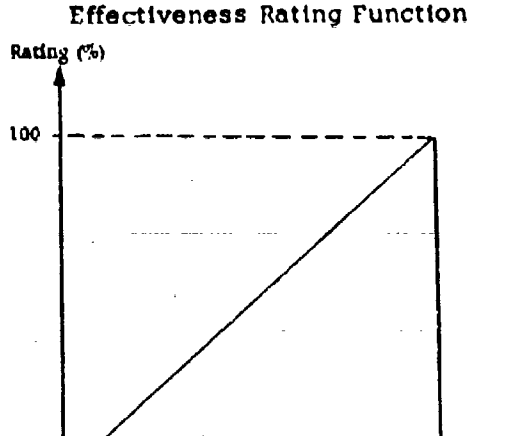
(a) There is some significant redundancy in the WMS subsystem's major components ($Z_{C/T}$, $ZB_{T/D}$, $ZG_{T/D}$ = 1)

(b) There is no significant redundancy in the WMS subsystem's major components ($Z_{C/T}$, $ZB_{T/D}$, $ZG_{T/D}$ = 0)

M/E VI - RELIABILITY

24	Degree of equipment failure independence*

Effectiveness Rating Function



$$R_i(\%) = \frac{100}{M} Z \qquad 0 \le Z \le 28$$

$$Z = 4 Z_{C/T} + 2 ZB_{T/D} + ZG_{T/D}$$

R_i (%) - Rating (%) of ith viable candidate WMS (independent of vessel)

Z - Failure independence index for WMS

$ZB_{C/T}$ - Failure independence index for (black water) C/T subsystem

$ZB_{T/D}$ - Failure independence index for WMS black water T/D subsystem

$ZG_{T/D}$ - Failure independence index for gray water T/D subsystem

M - Maximum possible value of Z=4x4+2x4+4 = 28

* I.e., failure of one item will not result in failure of major component or subsystem.

(Continued)

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Con Anal.
✓		

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1					a,b,b	79						
2					a,b,b	79					N	A
3			N	A	a,b,b	79					N	A
4			N	A	a,c,b	64					N	A
5	N	A	N	A	a,c,c	57					N	A
6	N	A	N	A	a,b,c	71					N	A
7			N	A	a,c,b	64					N	A
8	N	A	N	A	a,c,c	57					N	A
9					c,b,b	21						
10					c,c,b	7					N	A
11			N	A	c,b,b	21						
12	N	A	N	A	c,b,c	14					N	A
13	N	A	N	A	c,c,c	0					N	A
14					b,b,b	50						
15					b,c,b	36					N	A
16					b,b,b	50						
17	N	A	N	A	b,b,c	43					N	A
18	N	A	N	A	b,c,c	29					N	A

Attribute Data → ← Rating

N/A - Not a viable system/vessel combination

Data given in the form (not vessel dependent):

$Z_{C/T}$, $ZB_{T/D}$, $ZG_{T/D}$

Definition and values for $Z_{C/T}$, $ZB_{T/D}$, $ZG_{T/D}$

(a) There is high degree of equipment failure independence in WMS subsystem ($Z_{C/T}$, $ZB_{T/D}$, $ZG_{T/D}$ = 4)

(b) There is a moderate degree of equipment failure independence in WMS subsystem ($Z_{C/T}$, $ZB_{T/D}$, $ZG_{T/D}$ = 2)

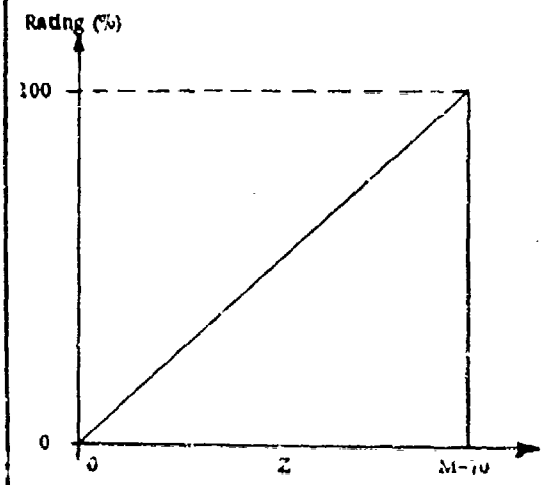
(c) There is a low degree of equipment failure independence in WMS subsystem ($Z_{C/T}$, $ZB_{T/D}$, $ZG_{T/D}$ = 0)

M/E VI - RELIABILITY

25 Adequacy of WMS equipment ratings

Effectiveness Rating Function

$$R_i(\%) = \frac{100}{M} Z \qquad 0 \le Z \le 70$$



$$Z = 4\,Z_{C/T} + 2\,ZB_{T/D} + ZG_{T/D}$$

$R_i(\%)$ - Rating (%) of ith viable candidate WMS (independent of vessel)

Z - Equipment rating index for WMS

$ZB_{C/T}$ - Equipment rating index for (black water) C/T subsystem

$ZB_{T/D}$ - Equipment rating index for WMS black water T/D subsystem

$ZG_{T/D}$ - Equipment rating index for gray water T/D subsystem

M - Maximum possible value of $Z = 4(10) + 2x10 + 10 = 70$

Source of Data		
MSD Anal:	WMS Trade-off Anal.	WMS Cost Anal.
✓		

(Continued)

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1					b,b,b	80						
2					b,c,b	63					N	A
3			N	A	b,c,b	63					N	A
4			N	A	b,c,b	63					N	A
5	N	A	N	A	b,c,c	54					N	A
6	N	A	N	A	b,b,c	71					N	A
7			N	A	b,c,b	63					N	A
8	N	A	N	A	b,c,c	54					N	A
9					b,b,b	80						
10					b,b,b	80					N	A
11			N	A	b,b,b	80						
12	N	A	N	A	b,b,c	71					N	A
13	N	A	N	A	b,b,c	71					N	A
14					b,b,b	80						
15					b,b,b	80					N	A
16					b,b,b	80						
17	N	A	N	A	b,b,c	71					N	A
18	N	A	N	A	b,b,c	71					N	A

Attribute Data ↑ ↑ Rating

N/A - Not a viable system/vessel combination

Data given in the form (not vessel dependent):

$$Z_{C/T},\ ZB_{T/D},\ ZG_{T/D}$$

Definition and values for $Z_{C/T},\ ZB_{T/D},\ ZG_{T/D}$

(a) Most WMS subsystem equipments are overrated
($Z_{C/T},\ ZB_{T/D},\ ZG_{T/D} = 10$)

(b) Some WMS subsystem equipment ratings are nominal, some are overrated
($Z_{C/T},\ ZB_{T/D},\ ZG_{T/D} = 8$)

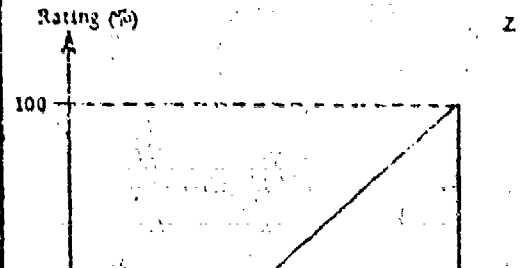
(c) Some WMS subsystem equipments are underrated, some are nominally rated ($Z_{C/T},\ ZB_{T/D},\ ZG_{T/D} = 2$)

(d) Most WMS subsystem equipments are underrated
($Z_{C/T},\ ZB_{T/D},\ ZG_{T/D} = 0$)

26 Provisions for fault actuated cut-off mechanisms* for WMS protection

Effectiveness Rating Function

$R_i(\%) = \frac{100}{M} Z \quad | \quad 0 \leq Z \leq 28$



$Z = 4 Z_{C/T} + 2 ZB_{T/D} + ZG_{T/D}$

$R_i(\%)$ - Rating (%) of ith viable candidate WMS (independent of vessel)

Z - Fault actuated cut-off mechanism index for WMS

$Z_{C/T}$ - Fault actuated cut-off mechanism index for (black water) Collection/Transport subsystem

$ZB_{T/D}$ - Fault actuated cut-off mechanism index for WMS black water Treatment/Disposal subsystem

$ZG_{T/D}$ - Fault actuated cut-off mechanism index for gray water Treatment/Disposal subsystem

M - Maximum possible value of $Z = 4 \times 4 + 2 \times 4 + 4 = 28$

Data given in the form (not vessel dependent):

$Z_{C/T}, ZB_{T/D}, ZG_{T/D}$

(Continued)

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1					a,b,b	79						
2					a,b,b	79					N	A
3			N	A	a,b,b	79					N	A
4			N	A	a,b,b	79					N	A
5	N	A	N	A	a,b,b	79					N	A
6	N	A	N	A	a,b,b	79					N	A
7			N	A	a,b,b	79					N	A
8	N	A	N	A	a,b,b	79					N	A
9					b,b,b	50						
10					b,a,b	64					N	A
11			N	A	b,b,b	50						
12	N	A	N	A	b,b,b	50					N	A
13	N	A	N	A	b,a,b	64					N	A
14					c,b,b	21						
15					c,a,b	36					N	A
16					c,b,b	21						
17	N	A	N	A	c,b,b	21					N	A
18	N	A	N	A	c,a,b	36					N	A

Attribute Data → ← Rating

N/A - Not a viable system/vessel combination

Definition and values for $Z_{C/T}$, $ZB_{T/D}$, $ZG_{T/D}$

(a) There are many fault-actuated mechanisms in WMS subsystem, or they are not required † ($Z_{C/T}$, $ZB_{T/D}$, $ZB_{T/D}$ = 4)

(b) There are some fault-actuated mechanisms in WMS subsystem ($Z_{C/T}$, $ZB_{T/D}$, $ZG_{T/D}$ = 2)

(c) There are no or almost no fault-actuated mechanisms in WMS subsystem ($Z_{C/T}$, $ZB_{T/D}$, $ZG_{T/D}$ = 0)

---

* Include mechanisms to:
(1) Alert operator/maintainer to high stress or abnormal condition that will result in failure.

(2) Correct those conditions or turn off equipment.

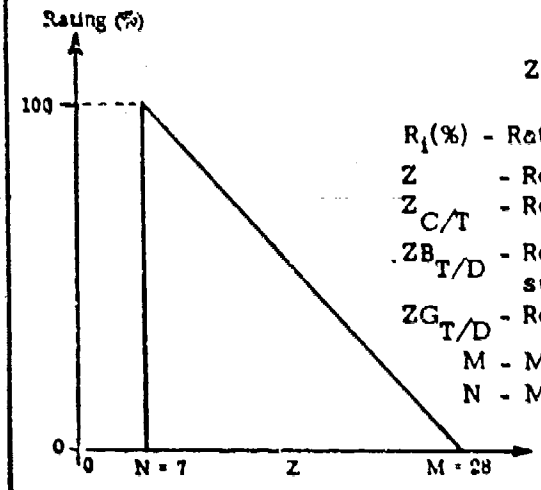
† E.g., standard commodes and urinals in a gravity drain sewage collection subsystem do not require fault actuated cut-off mechanisms.

M/E VI - RELIABILITY

3	Reliability risk for WMS*

Effectiveness Rating Function

$$R_i(\%) = 100 - \frac{100}{21}(Z-7) \qquad 7 \le Z \le 28$$



$$Z = 4Z_{C/T} + 2ZB_{T/D} + ZG_{T/D}$$

$R_i(\%)$ - Rating (%) of ith viable WMS (independent of vessel)

Z - Reliability risk index for WMS

$Z_{C/T}$ - Reliability risk index for (black water) C/T subsystem

$ZB_{T/D}$ - Reliability risk index for WMS black water T/D subsystem

$ZG_{T/D}$ - Reliability risk index for gray water T/D subsystem

M - Maximum possible value of Z = 4x4+2x4+4 = 28

N - Minimum value of Z = 4+2+1 = 7

Source of Rate		
MSD Anal.	WMS Install. Anal.	WMS Con Anal.
✓		

* Innovative design, experience, etc.

(Cont'd.)

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1					a,a,a	100						
2					a,a,a	100					N	A
3			N	A	a,b,a	71					N	A
4			N	A	a,b,a	71					N	A
5	N	A	N	A	a,b,b	57					N	A
6	N	A	N	A	a,a,b	86					N	A
7			N	A	a,b,a	71					N	A
8	N	A	N	A	a,b,b	57					N	A
9					a,a,a	100						
10					a,b,a	71					N	A
11			N	A	a,a,a	100						
12	N	A	N	A	a,a,b	86					N	A
13	N	A	N	A	a,b,b	57					N	A
14					a,a,a	100						
15					a,b,a	71					N	A
16					a,a,a	100						
17	N	A	N	A	a,a,b	86					N	A
18	N	A	N	A	a,b,b	57					N	A

Attribute Data — Rating

N/A - Not a viable system/vessel combination

Data given in the form (not vessel dependent):

$$Z_{C/T},\ ZB_{T/D}\ ,\ ZG_{T/D}$$

Definition and values for $Z_{C/T}$, $ZB_{T/D}$, $ZG_{T/D}$

(a) WMS subsystem has a history of fair or better test results

($Z_{C/T}$, $ZB_{T/D}$, $ZG_{T/D}$ = 1)

(b) WMS subsystem has a history of poor test results

($Z_{C/T}$, $ZB_{T/D}$, $ZG_{T/D}$ = 4)

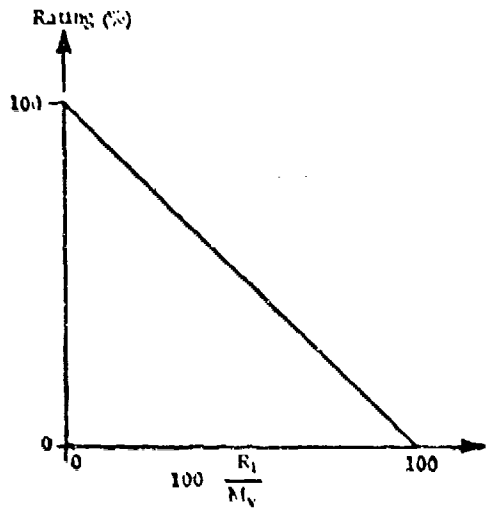
(c) No test results are available for WMS subsystem

($Z_{C/T}$, $ZB_{T/D}$, $ZG_{T/D}$ = 3)

M/E VII - MAINTAINABILITY

11	Frequency of WMS corrective maintenance (CM) actions (failure frequency-relative)

Effectiveness Rating Function



$$R_{iv}(\%) = 100 - 100\,\frac{R_i}{M_v} \qquad 0 \le \frac{R_i}{M_v} \le 1.0$$

$R_{iv}(\%)$ - Rating (%) of ith viable candidate WMS on vessel v

R_i - Estimated annual number of repairs for the ith viable candidate WMS on vessel v based on projected WMS utilization.

M_v - Maximum value of R_i for all viable WMS candidates for a given vessel v.

Source of Data

MSD Anal.	WMS Maint. Anal.	WMS Cost Anal.

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

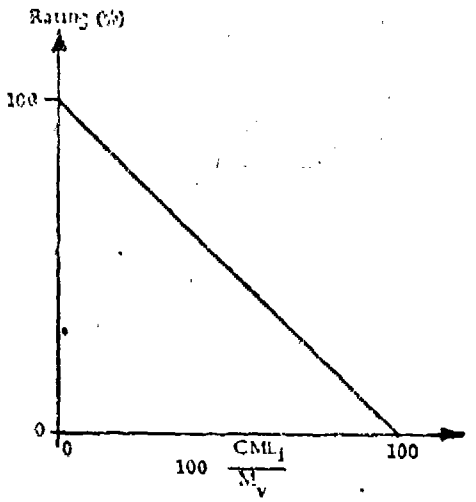
WMS #	GALIATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	22	96	24	94	10	96	16	84	10	91	5	89
2	68	88	30	92	20	93	26	74	24	78	N	A
3	74	87	N	A	21	93	26	74	24	78	N	A
4	44	92	N	A	18	94	27	73	15	86	N	A
5	N	A	N	A	23	92	24	76	14	87	N	A
6	N	A	N	A	23	92	24	76	15	86	N	A
7	44	92	N	A	18	94	27	73	16	86	N	A
8	N	A	N	A	26	91	24	76	12	89	N	A
9	547	3	396	1	259	8	83	17	105	5	47	0
10	562	0	399	0	280	0	100	0	111	0	N	A
11	562	0	N	A	264	6	86	14	106	5	47	0
12	N	A	N	A	271	3	96	4	109	2	N	A
13	N	A	N	A	268	4	93	7	109	2	N	A
14	197	65	110	72	46	84	39	61	61	45	18	62
15	203	64	119	70	66	76	56	44	67	40	N	A
16	212	62	113	72	51	82	42	58	62	44	18	62
17	N	A	N	A	58	79	52	48	65	41	N	A
18	N	A	N	A	55	80	48	51	65	41	N	A

Attribute Data ↑ ↑ Rating

N/A - Not a viable system/vessel combination

12	Man-hour and skill level requirements for WMS CM actions (relative)

Effectiveness Rating Function



$$R_{iv}(\%) = 100 - 100\,\frac{CML_i}{M_v} \qquad 0 \le \frac{CML_i}{M_v} \le 1.0$$

$R_{iv}(\%)$ - Rating (%) of ith viable candidate WMS on vessel v

CML_i - Estimated annual CM labor cost ($/Year) for i^{th} viable candidate WMS on vessel v based on projected WMS utilization

M_v - Maximum value of CML_i for all viable WMS candidates for a given vessel v

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
		✓

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	174	94	98	94	38	95	55	90	39	92	30	90
2	632	78	257	83	240	66	228	58	240	51	N	A
3	642	78	N	A	240	65	233	57	242	51	N	A
4	129	96	N	A	58	92	89	84	57	88	N	A
5	N	A	N	A	69	90	79	86	54	89	N	A
6	N	A	N	A	69	90	79	86	57	88	N	A
7	154	95	N	A	74	90	125	77	73	85	N	A
8	N	A	N	A	113	84	116	79	68	86	N	A
9	1358	54	979	35	611	14	189	66	172	65	97	67
10	1440	51	996	34	650	9	236	57	192	61	N	A
11	1419	52	N	A	634	11	207	62	179	64	99	67
12	N	A	N	A	641	10	223	59	184	63	N	A
13	N	A	N	A	685	4	250	54	194	61	N	A
14	2868	2	1483	2	639	10	487	11	471	4	295	1
15	(2933)	0	1500	1	678	5	534	3	491	0	N	A
16	2929	0	(1517)	0	662	7	505	8	478	3	(297)	0
17	N	A	N	A	669	6	521	5	483	2	N	A
18	N	A	N	A	(713)	0	(548)	0	(493)	0	N	A

Attribute Data ↑ ↑ Rating

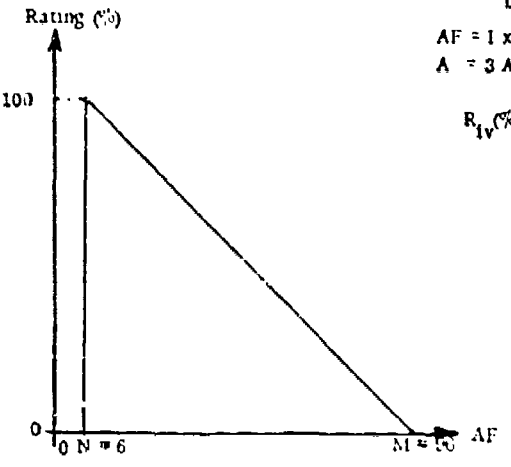
N/A -- Not a viable system/vessel combination

M/E VII - MAINTAINABILITY

131 Accessibility of replaceable WMS components

Effectiveness Rating Function

$R_{iv}(\%) = 100 - \frac{100}{90}(AF - 6) \quad 6 \le AF \le 96$



$AF = I \times A$

$A = 3A_{C/T} + 2AB_{T/D} + AG_{T/D}$

$R_{iv}(\%)$ - Rating (%) of ith viable candidate WMS on vessel v

AF - WMS and installation accessibility factor
I - Installation index (for accesibility)
A - WMS accessibility index
$A_{C/T}$ - Accessibility index for WMS (black water) Collection/ Transport subsystem
$AB_{T/D}$ - Accessibility index for black water Treatment/ Disposal subsystem
$AG_{T/D}$ - Accessibility index for WMS gray water Treatment/ Disposal subsystem
M - Maximum possible value of AF = 4(3 x 4 + 2 x 4 + 4) = 96
N - Minimum value of AF = 1(3x1+2x1+1) = 6

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
✓	✓	

(Continued)

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	b/	87	b/	87	b/ a, b, b	87	b/	87	a/	97	c/	67
2	b/	80	b/	80	b/ b, b, b	80	b/	80	b/	80	N	A
3	b/	80	N	A	b/ b, b, b	80	b/	80	c/	53	N	A
4	b/	78	N	A	b/ a, c, b	78	c/	49	b/	78	N	A
5	N	A	N	A	b/ a, c, c	73	b/	73	a/	90	N	A
6	N	A	N	A	b/ a, b, c	82	b/	82	a/	94	N	A
7	b/	78	N	A	b/ a, c, b	78	b/	78	a/	92	N	A
8	N	A	N	A	b/ a, c, c	73	b/	73	a/	90	N	A
9	b/	67	b/	67	b/ c, b, b	67	b/	67	a/	87	c/	27
10	b/	67	b/	67	b/ c, b, b	67	b/	67	c/	27	N	A
11	b/	58	N	A	b/ c, c, b	58	b/	58	a/	82	c/	9
12	N	A	N	A	b/ c, b, c	62	c/	18	b/	62	N	A
13	N	A	N	A	b/ c, b, c	62	b/	62	a/	84	N	A
14	b/	67	b/	67	b/ c, b, b	67	b/	67	a/	87	c/	27
15	b/	67	c/	27	b/ c, b, b	67	b/	67	b/	67	N	A
16	b/	58	c/	9	b/ c, c, b	58	b/	58	a/	82	c/	9
17	N	A	N	A	b/ c, b, c	62	b/	62	b/	62	N	A
18	N	A	N	A	b/ c, b, c	62	b/	62	b/	62	N	A

Attribute Data ↑ ↑ Rating

N/A = Not a viable system/vessel combination

VII - 131

Definitions and values for I

(a) High degree of physical clearance around WMS equipment (I = 1)

(b) Moderate degree of clearance around WMS equipment (I = 2)

(c) Very tight, i.e., very little clearance around WMS equipment (I = 4)

Definitions and values for $A_{C/T}$, $AB_{T/D}$, $AG_{T/D}$

(a) High degree of accessibility in WMS subsystem ($A_{C/T}$, $AB_{T/D}$, $AG_{T/D}$ = 1)

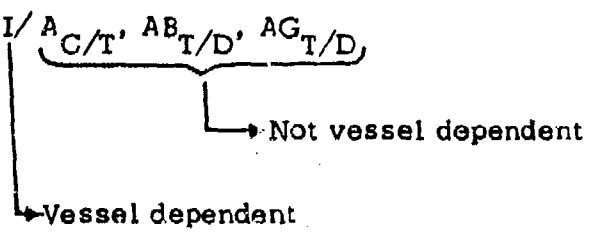
(b) Moderate degree of accessibility in WMS subsystem

(A_{CT}, $AB_{T/D}$, $AG_{T/D}$ = 2)

(c) Low degree of accessibility in WMS subsystem

($A_{C/T}$, $AB_{T/D}$, $AG_{T/D}$ = 4)

WMS/vessel data given in the form:

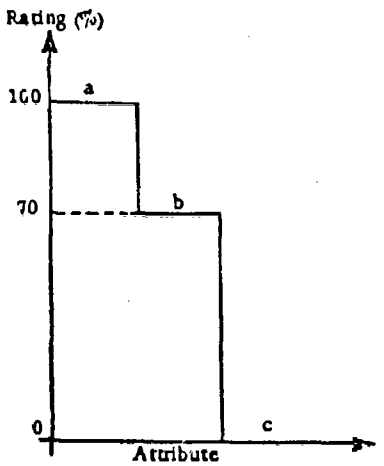


M/E VII - MAINTAINABILITY

132	Extent of WMS modularization for ease of repair/replacement

Effectiveness Rating Function

$R_{WMS} = \text{Min}\,(R_{C/T}, RB_{T/D}, RG_{T/D})$



R_{WMS} - Rating for WMS

$R_{C/T}$ - Rating for (black water) C/T subsystem

$RB_{T/D}$ - Rating for black water T/D subsystem

$RG_{T/D}$ - Rating for gray water T/D subsystem

Data given in the form (not vessel dependent):

$Z_{C/T}$ · $ZB_{T/D}$ · $ZG_{T/D}$ } Attribute Data

$R_{C/T}$ $RB_{T/D}$ $RG_{T/D}$ } Ratings

Definitions of $Z_{C/T}$, $ZB_{T/D}$, $ZG_{T/D}$

(a) High degree of WMS subsystem modularization
(b) Moderate degree of WMS subsystem modularization
(c) Low degree of WMS subsystem modularization

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
✓		

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1					a, a, b	70						
2					a, a, b	70					N	A
3			N	A	a, a, b	70					N	A
4			N	A	a, b, b	70					N	A
5	N	A	N	A	a, b, b	70					N	A
6	N	A	N	A	a, b, b	70					N	A
7			N	A	a, b, b	70					N	A
8	N	A	N	A	a, b, b	70					N	A
9					c, b, b	0						
10					c, b, b	0					N	A
11			N	A	c, a, b	0						
12	N	A	N	A	c, b, b	0					N	A
13	N	A	N	A	c, c, b	0					N	A
14					b, b, b	70						
15					b, c, b	0					N	A
16					b, a, b	70						
17	N	A	N	A	b, b, b	70					N	A
18	N	A	N	A	b, c, b	0					N	A

Attribute Data — Rating

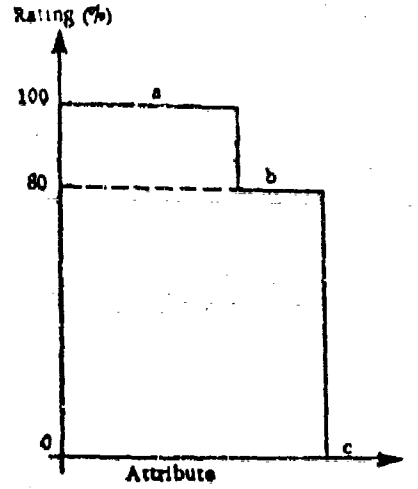
N/A - Not a viable system/vessel combination

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E _____ VII - MAINTAINABILITY

133	Degree of WMS repairability* on board vessel

Effectiveness Rating Function



$R_{WMS} = \text{Min}\,(R_{C/T}, RB_{T/D}, RG_{T/D})$

R_{WMS} - Rating for WMS

$R_{C/T}$ - Rating for (black water) C/T subsystem

$RB_{T/D}$ - Rating for black water T/D subsystem

$RG_{T/D}$ - Rating for gray water T/D subsystem

Data given in the form (not vessel dependent):

$Z_{C/T}, ZB_{T/D}, ZG_{T/D}$ } Attribute

$R_{C/T}, RB_{T/D}, RG_{T/D}$ } Ratings

Definition of $Z_{C/T}, ZB_{T/D}, ZG_{T/D}$

(a) All WMS subsystem items are repairable on vessel.

(b) Some WMS subsystem items are repairable on vessel; some must be replaced.

(c) All WMS subsystem items must be replaced.

* Versus necessity for replacement of failed equipment.

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Con Anal.
✓		

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1					a, a, a	100						
2					a, a, a	100					N	A
3			N	A	a, b, a	80					N	A
4			N	A	b, b, a	80					N	A
5	N	A	N	A	b, b, b	80					N	A
6	N	A	N	A	a, a, b	80					N	A
7			N	A	b, b, a	80					N	A
8	N	A	N	A	b, b, b	80					N	A
9					b, a, a	80						
10					b, b, a	80					N	A
11			N	A	b, b, a	80						
12	N	A	N	A	b, a, b	80					N	A
13	N	A	N	A	b, b, b	80					N	A
14					a, a, a	100						
15					a, b, a	80					N	A
16					a, b, a	80						
17	N	A	N	A	a, a, b	80					N	A
18	N	A	N	A	a, b, b	80					N	A

Attribute Data ↑ ↑ Rating

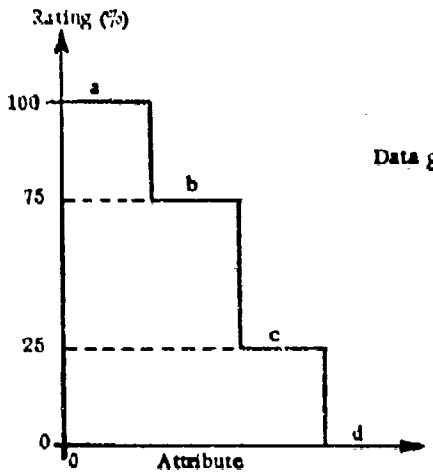
N/A - Not a viable system/vessel combination

M/E _____ VII - MAINTAINABILITY

134 Availability of manufacturer field and training programs for WMS

Effectiveness Rating Function

$R_{WMS} = \text{Min}\,(R_{C/T}, RB_{T/D}, RG_{T/D})$



R_{WMS} - Rating for WMS
$R_{C/T}$ - Rating for (black water) C/T subsystem
$RB_{T/D}$ - Rating for black water T/D subsystem
$RG_{T/D}$ - Rating for gray water T/D subsystem

Data given in the form (not vessel dependent):

$\left.\begin{matrix} Z_{C/T} \\ R_{C/T} \end{matrix}\right\}$ Attribute
$\left.\begin{matrix} ZB_{T/D} \\ RB_{T/D} \end{matrix}\right\}$ Attribute
$\left.\begin{matrix} ZG_{T/D} \\ RG_{T/D} \end{matrix}\right\}$ Ratings

Definitions of $Z_{C/T}$, $ZB_{T/D}$, $ZG_{T/D}$

(a) Manufacturer field support and a training program is available.
(b) Manufacturer field support* is available but no training program is available.
(c) Manufacturer training program is available but field support is not available.
(d) Neither field support nor a training program are available from manufacturer.

* May include some limited training support during initial WMS installation.

Data for Manufacturer Support Availability

MSD	Field Support Available	Training Program Available
[illegible]	Yes	Yes
CNT	Yes	Yes
GATX	Yes	No
Grumman	Yes	No
Chrysler	Yes	No
[illegible]	Yes	No

* Data to Chrysler was provided by Manufacturer.
- All other data was supplied by the C.G.

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Con Anal.
✓		

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1					a, a, a	100						
2					b, b, a	75					N	A
3			N	A	b, b, a	75					N	A
4			N	A	b, b, a	75					N	A
5	N	A	N	A	b, b, b	75					N	A
6	N	A	N	A	a, a, b	75					N	A
7			N	A	b, b, a	75					N	A
8	N	A	N	A	b, b, b	75					N	A
9					a, a, a	100						
10					a, a, a	100					N	A
11			N	A	a, b, a	75						
12	N	A	N	A	a, a, b	75					N	A
13	N	A	N	A	a, a, b	75					N	A
14					b, a, a	75						
15					b, a, a	75					N	A
16					b, b, a	75						
17	N	A	N	A	b, a, b	75					N	A
18	N	A	N	A	b, a, b	75					N	A

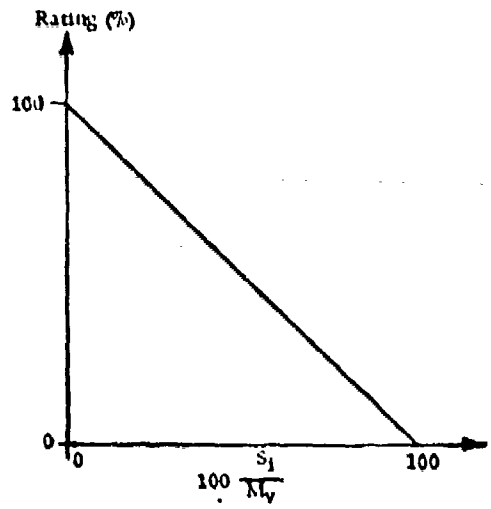
Attribute Data ↑ ↑ Rating

N/A - Not a viable system/vessel combination

M/E _____ VII - MAINTAINABILITY

141 Extent of spares stockage required for WMS equipment repairs (relative)

Effectiveness Rating Function



$$R_{iv}(\%) = 100 - 100\,\frac{S_i}{M_v} \qquad 0 \le \frac{S_i}{M_v} \le 1.0$$

$R_{iv}(\%)$ - Rating (%) of ith viable candidate WMS on vessel v

S_i - Estimated annual number of spare parts required for i^{th} viable candidate WMS on vessel v based on projected WMS utilization

M_v - Maximum value of S_i for all viable WMS candidates for a given vessel v

NOTES: 1. Weight and volume of spares not considered.
2. Amount based on MTBF, either manufacturer supplied or estimated.

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Con Anal. ✓

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

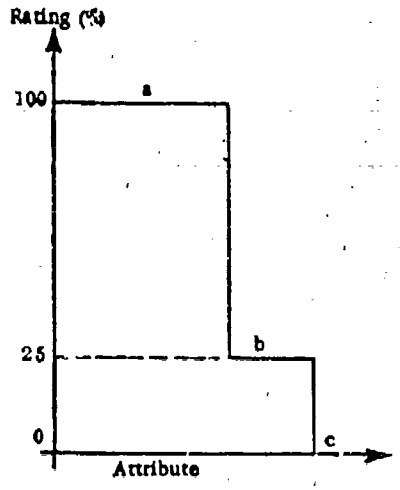
WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	25	88	12	88	6	90	12	77	6	90	1	95
2	65	69	25	75	20	68	25	52	19	67	N	A
3	71	66	N	A	23	63	23	56	19	67	N	A
4	35	83	N	A	14	78	26	50	1	88	N	A
5	N	A	N	A	20	68	22	58	10	83	N	A
6	N	A	N	A	20	68	22	58	11	81	N	A
7	35	83	N	A	14	78	27	48	11	81	N	A
8	N	A	N	A	24	62	23	56	10	83	N	A
9	159	24	99	0	50	21	36	31	30	48	(19)	0
10	158	24	(99)	0	51	19	37	29	31	47	N	A
11	163	22	N	A	51	19	34	35	30	48	18	5
12	N	A	N	A	(63)	0	50	4	35	40	N	A
13	N	A	N	A	59	6	46	12	34	41	N	A
14	204	92	76	23	34	46	31	40	53	9	14	26
15	204	2	76	23	35	44	32	38	54	7	N	A
16	(208)	0	77	23	35	44	42	19	53	9	13	32
17	N	A	N	A	47	25	(52)	0	(58)	0	N	A
18	N	A	N	A	43	32	42	19	57	2	N	A

Attribute Data ↑ ↑ Rating

N/A - Not a viable system/vessel combination

142 Special/proprietary* item requirements for WMS equipment repair

Effectiveness Rating Function



$R_{WMS} = \text{Min}(R_{C/T}, RB_{T/D}, RG_{T/D})$

R_{WMS} - Rating for WMS

$R_{C/T}$ - Rating for (black water) C/T subsystem

$RB_{T/D}$ - Rating for black water T/D subsystem

$RG_{T/D}$ - Rating for gray water T/D subsystem

Data given in the form (not vessel dependent):

$(Z_{C/T}, ZB_{T/D}, ZG_{T/D})$ Attribute

$(R_{C/T}, RB_{T/D}, RG_{T/D})$ Ratings

Definitions of $Z_{C/T}, ZB_{T/D}, ZG_{T/D}$

(a) No special items required for any WMS subsystem repairs.
(b) Some special items required for some WMS subsystem repairs.
(c) All items required for WMS repairs are special items.

* Incinerator pots, filters etc., versus standard supply parts.

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
✓		

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1					a, a, a	100						
2					a, b, a	25					N	A
3			N	A	a, b, a	25					N	A
4			N	A	a, b, a	25					N	A
5	N	A	N	A	a, b, b	25					N	A
6	N	A	N	A	a, a, b	25					N	A
7			N	A	a, b, a	25					N	A
8	N	A	N	A	a, b, b	25					N	A
9					b, a, a	25						
10					b, b, a	25					N	A
11			N	A	b, b, a	25						
12	N	A	N	A	b, a, b	25					N	A
13	N	A	N	A	b, b, b	25					N	A
14					b, a, a	25						
15					b, b, a	25					N	A
16					b, b, a	25						
17	N	A	N	A	b, a, b	25					N	A
18	N	A	N	A	b, b, b	25					N	A

Attribute Data ↑ ↑ Rating

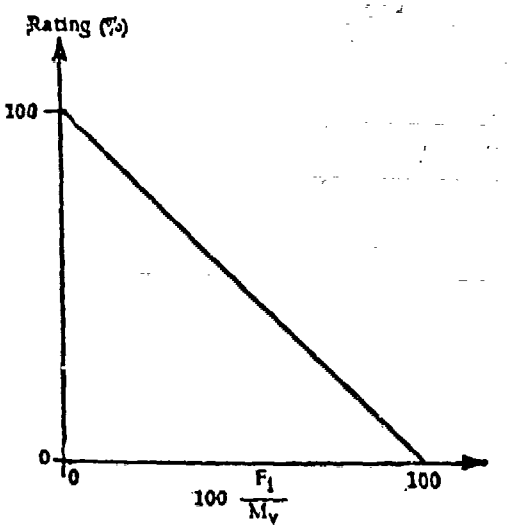
N/A - Not a viable system/vessel combination

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E _____ VII - MAINTAINABILITY

21	Frequency of PM actions (relative)

Effectiveness Rating Function



$$R_{iv}(\%) = 100 - 100\,\frac{F_i}{M_v} \qquad 0 \le \frac{F_i}{M_v} \le 1.0$$

$$F_i = \sum_j w_j f_j$$

j = All PM actions for i^{th} viable candidate WMS on vessel v

$R_{iv}(\%)$ = Rating (%) of ith viable candidate WMS on vessel v

F_i = Annual number of WMS PM actions

f_j = Number of WMS PM actions at j^{th} periodicity

w_j = Penalty weight for j^{th} periodicity of PM action

M_v = Maximum value of F_i for all viable WMS candidates for a given vessel v

Periodicity (j) (Hours)	w_j
24 (Daily)	365
168 (Weekly)	52
730 (Monthly)	12
2,190 (Quarterly)	4
4,380 (Semi-Annually)	2
8,760 (Annually	1

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
		✓

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	168	95	84	95	70	91	84	89	84	89	70	90
2	249	92	111	93	89	89	111	86	111	86	N	A
3	443	86	N	A	211	73	197	75	197	76	N	A
4	364	88	N	A	182	77	182	77	182	77	N	A
5	N	A	N	A	266	66	168	79	168	79	N	A
6	N	A	N	A	266	66	168	79	182	77	N	A
7	384	88	N	A	196	75	192	76	192	76	N	A
8	N	A	N	A	356	55	178	78	178	78	N	A
9	1454	53	583	63	349	56	691	13	691	13	633	14
10	1470	53	590	62	305	61	701	12	701	12	N	A
11	2352	24	N	A	677	15	(794)	0	(794)	0	(736	0
12	N	A	N	A	597	25	789	1	789	1	N	A
13	N	A	N	A	655	17	240	70	240	70	N	A
14	2202	29	1113	29	512	35	399	50	399	50	270	63
15	2140	31	1121	28	524	34	409	48	409	48	N	A
16	(3100)	0	(1562)	0	(792)	0	502	37	502	37	373	49
17	N	A	N	A	712	10	493	38	493	38	N	A
18	N	A	N	A	770	3	481	39	481	39	N	A

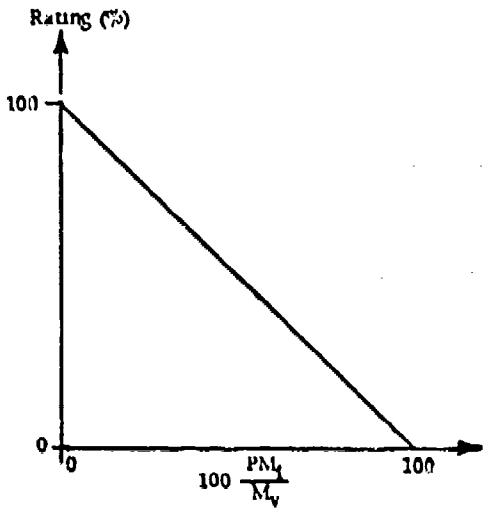
Attribute Data ↑ ↑ Rating

N/A - Not a viable system/vessel combination

M/E VII - MAINTAINABILITY

22	Man-hours required for WMS PM actions (relative)

Effectiveness Rating Function



$$R_{iv}(\%) = 100 - 100\,\frac{PM_i}{M_v} \qquad 0 \leq \frac{PM_i}{M_v} \leq 1.0$$

$R_{iv}(\%)$ - Rating (%) of ith viable candidate WMS on vessel v

PM_i - Annual PM man-hours required for i^{th} viable candidate WMS on vessel v

M_v - Maximum value of PM_i for all viable WMS candidates for a given vessel v

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
		✓

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	71	90	36	90	30	86	36	73	36	73	30	76
2	98	86	45	87	39	82	44	67	45	66	N	A
3	62	91	N	A	29	87	25	81	25	81	N	A
4	106	85	N	A	53	76	53	60	53	60	N	A
5	N	A	N	A	65	70	48	64	48	64	N	A
6	N	A	N	A	65	70	48	64	48	64	N	A
7	67	91	N	A	33	85	33	75	33	75	N	A
8	N	A	N	A	56	74	28	79	28	79	N	A
9	313	56	179	50	150	31	115	14	115	14	107	15
10	306	57	175	51	146	33	96	28	96	28	N	A
11	544	23	N	A	(217)	0	(134)	0	(134)	0	(126)	0
12	N	A	N	A	184	15	132	1	132	1	N	A
13	N	A	N	A	164	24	108	19	108	19	N	A
14	476	33	244	32	122	44	100	25	100	25	70	44
15	442	37	240	33	119	45	80	40	80	40	N	A
16	(707)	0	(359)	0	189	13	118	12	118	12	93	26
17	N	A	N	A	157	28	117	13	117	13	N	A
18	N	A	N	A	137	37	92	31	92	31	N	A

Attribute Data ↑ ↑ Rating

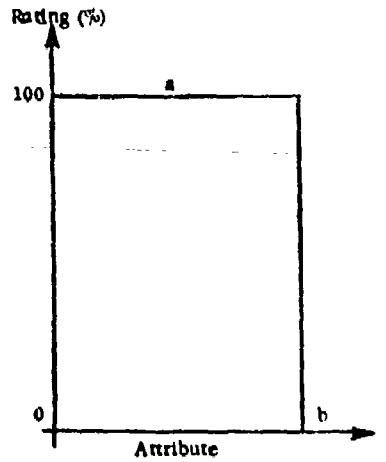
N/A - Not a viable system/vessel combination

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E VII - MAINTAINABILITY

23	Effect of WMS PM on vessel watchstander routines

Effectiveness Rating Function



R_{jv}(%) - Rating (%) of jth viable candidate WMS on vessel v

(a) No effect on watchstander routines. *

(b) There is some effect on watchstander routines.

* By C.G. direction, (a) applies to all WMS considered in this study.

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
✓		

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	a	100			a	100						
2											N	A
3			N	A							N	A
4			N	A							N	A
5	N	A	N	A							N	A
6	N	A	N	A							N	A
7			N	A							N	A
8	N	A	N	A							N	A
9												
10											N	A
11			N	A								
12	N	A	N	A							N	A
13	N	A	N	A							N	A
14												
15											N	A
16												
17	N	A	N	A							N	A
18	N	A	N	A							N	A

Attribute Data ↑ ← Rating

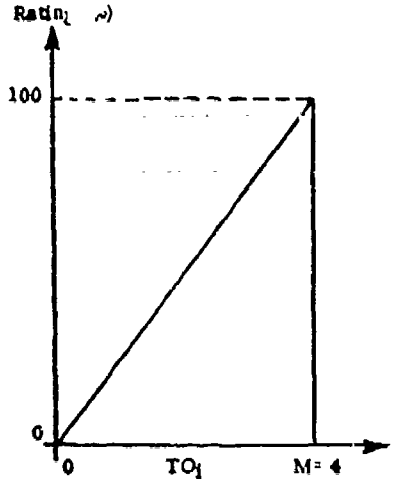
N/A - Not a viable system/vessel combination

M/E VII - MAINTAINABILITY

31	Frequency of WMS overhauls

Effectiveness Rating Function

$R_i(\%) = 100\,(TO_i/M) \quad 0 \leq \frac{TO_i}{M} \leq 1.0$



$R_i(\%)$ - Rating (%) of ith viable candidate WMS (independent of vessel)

TO_i - Minimum time between overhauls (in years) of any subsystem of the ith viable candidate WMS (independent of vessel)

M - Maximum value of TO_i for all viable WMS candidates (independent of vessel)

NOTES:

1. For JERED large boat MSD and a CHT the time between overhauls is 4 years.
2. By C.G. direction, the time between overhauls for all other MSDs considered in this study is assumed to be 2 years.

Data given in the form (not vessel dependent):

TO_1 For (black water) C/T subsystem
TO_2 For black water T/D subsystem
TO_3 For gray water T/D subsystem

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Con Anal.
✓		

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1					4, 4, 4	100						
2					2, 2, 4	50					N	A
3			N	A	2, 2, 4	50					N	A
4			N	A	2, 2, 4	50					N	A
5	N	A	N	A	2, 2, 2	50					N	A
6	N	A	N	A	4, 4, 2	50					N	A
7			N	A	2, 2, 4	50					N	A
8	N	A	N	A	2, 2, 2	50					N	A
9					4, 4, 4	100						
10					4, 4, 4	100					N	A
11			N	A	4, 2, 4	50						
12	N	A	N	A	4, 4, 2	50					N	A
13	N	A	N	A	4, 4, 2	50					N	A
14					2, 4, 4	50						
15					2, 4, 4	50					N	A
16					2, 2, 4	50						
17	N	A	N	A	2, 4, 2	50					N	A
18	N	A	N	A	2, 4, 2	50					N	A

Attribute Data ↑ ↑ Rating

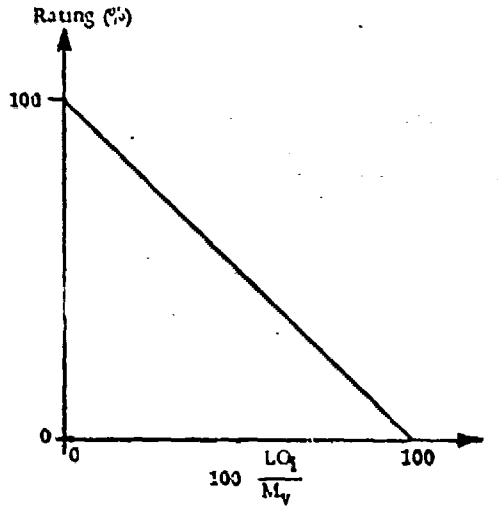
N/A - Not a viable system/vessel combination

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E VII - MAINTAINABILITY

32	Man-hour and skill level requirements for WMS overhauls (relative)

Effectiveness Rating Function



$$R_{iv}(\%)\ 100 - 100\ \frac{LO_i}{M_v} \qquad 0 \le \frac{LO_i}{M_v} \le 1.0$$

$R_{iv}(\%)$ - Rating (%) of ith viable candidate WMS on vessel v

LO_i - Cost of labor ($) for overhaul of ith viable candidate WMS on vessel v

M_v - Maximum value of LO_i for all viable WMS candidate for a given vessel v

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
		✓

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	988	59	613	66	424	79	604	17	604	17	420	14
2	1077	55	532	71	524	74	492	32	492	32	N	A
3	803	67	N	A	591	70	328	55	328	55	N	A
4	1249	48	N	A	730	63	(728)	0	728	0	N	A
5	N	A	N	A	671	66	546	25	546	25	N	A
6	N	A	N	A	671	66	546	25	(728)	0	N	A
7	1030	57	N	A	621	69	619	15	618	15	N	A
8	N	A	N	A	634	68	437	40	437	40	N	A
9	2316	4	(1823)	0	1734	12	436	40	436	40	420	14
10	2101	13	1715	6	1627	18	327	55	327	55	N	A
11	(2402)	0	N	A	1702	14	329	55	329	55	313	36
12	N	A	N	A	(1978)	0	558	23	558	23	N	A
13	N	A	N	A	1710	14	267	63	267	63	N	A
14	2079	13	1091	40	656	67	574	21	574	21	(488)	0
15	1789	26	983	46	548	72	464	36	464	36	N	A
16	2164	10	1134	38	624	68	467	36	467	36	382	22
17	N	A	N	A	899	55	696	4	696	4	N	A
18	N	A	N	A	631	68	405	44	405	44	N	A

Attribute Data ↑ ↑ Rating

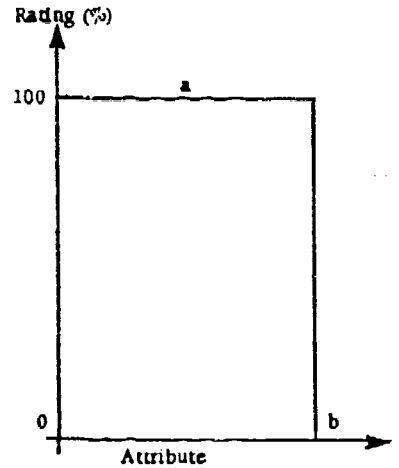
N/A - Not a viable system/vessel combination

EFFECTIVENESS RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

M/E VII - MAINTAINABILITY

33	Special docking requirements for WMS overhauls

Effectiveness Rating Function



(a) There are no special docking requirements for the WMS.*

(c) There are special docking requirements for the WMS.

* By C.G. direction, (a) applies to all WMS candidates in this study.

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
✓		

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1	a	100			a	100						
2											N	A
3			N	A							N	A
4			N	A							N	A
5	N	A	N	A							N	A
6	N	A	N	A							N	A
7			N	A							N	A
8	N	A	N	A							N	A
9												
10											N	A
11			N	A								
12	N	A	N	A							N	A
13	N	A	N	A							N	A
14												
15											N	A
16												
17	N	A	N	A							N	A
18	N	A	N	A							N	A

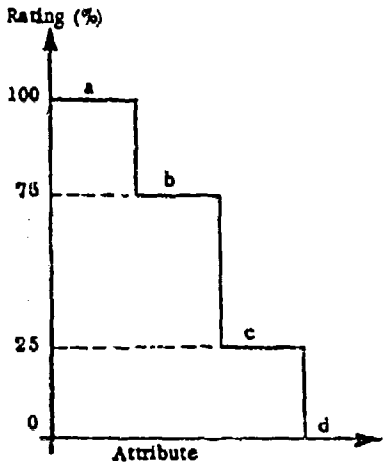
Attribute Data → ← Rating

N/A - Not a viable system/vessel combination

M/E VII - MAINTAINABILITY

4	Logistic requirements for WMS (relative)

Effectiveness Rating Function



R_{WMS} - Rating for WMS

$R_{C/T}$ - Rating for (black water) C/T subsystem

$RB_{T/D}$ - Rating for black water T/D subsystem

$RG_{T/D}$ - Rating for gray water T/D subsystem

$$R_{WMS} = \text{Min}\,(R_{C/T},\ RB_{T/D},\ RG_{T/D})$$

Data given in the form (not vessel dependent):

$(Z_{C/T},\ ZB_{T/D},\ ZG_{T/D})$ Attribute

$(R_{C/T}\ \ RB_{T/D}\ \ RG_{T/D})$ Ratings

Definitions of $Z_{C/T}$, $ZB_{T/D}$, $ZG_{T/D}$

(a) No special parts are required for the WMS subsystem.

(b) Few different categories of special parts are required for the WMS subsystem and there are few parts in each category.

(c) Few different categories of special parts are required for the WMS subsystem but many parts of each type are required; or, many different categories of special parts required, but there are few parts in each category.

(d) Many different categories of parts are required for the WMS subsystem and there is a large number of parts within each category.

Source of Data		
MSD Anal.	WMS Install. Anal.	WMS Cost Anal.
✓		

Effectiveness Attribute Data and Ratings for Viable System/Vessel Combinations

WMS #	GALLATIN (378')		VIGOROUS (210')		FIREBUSH (180')		PAMLICO (160')		WHITE SAGE (133')		POINT HERRON (82')	
1					a, a, a	100						
2					a, b, a	75					N	A
3			N	A	a, b, a	75					N	A
4			N	A	a, b, a	75					N	A
5	N	A	N	A	a, b, b	75					N	A
6	N	A	N	A	a, a, b	75					N	A
7			N	A	a, b, a	75					N	A
8	N	A	N	A	a, b, b	75					N	A
9					b, a, a	75						
10					b, b, a	75					N	A
11			N	A	b, b, a	75						
12	N	A	N	A	b, a, b	75					N	A
13	N	A	N	A	b, b, b	75					N	A
14					b, a, a	75						
15					b, b, a	75					N	A
16					b, b, a	75						
17	N	A	N	A	b, a, b	75					N	A
18	N	A	N	A	b, b, b	75					N	A

Attribute Data ↑ ↑ Rating

N/A - Not a viable system/vessel combination

DISCUSSION OF THE EFFECTIVENESS ASSESSMENT METHODOLOGY AND APPLICATION GUIDELINES

EFFECTIVENESS ASSESSMENT OF CANDIDATES

The effectiveness of candidate systems is determined on the basis of numerous considerations such as system characteristics and features, assumptions, etc. It is very difficult to make sound decisions based on the simultaneous judgement of a multitude of considerations, many of which may be unrelated. On the other hand, it is fairly easy to make individual decisions on a small scale. The approach used for assessing the effectiveness of candidates is based on converting the relatively difficult problem of trying to arrive at a major decision by simultaneously juggling numerous and often unrelated considerations, into the relatively easy problem of systematically making many "small" decisions. The approach also addresses the necessity of combining the decision-maker's subjective judgements with technical data and relevant assumptions in arriving at an overall effectiveness assessment of each candidate system.

The effectiveness assessment consists of the following three basic steps:

- Development of a suitable effectiveness model.
- Development of effectiveness attribute data.
- Quantification of effectiveness by substitution of the effectiveness attribute data into the effectiveness model.

The effectiveness model is, in effect, a framework of criteria for judging the degree of acceptability of each candidate system. This framework is in the form of a hierarchy which structures the effectiveness assessment criteria in successive levels of detail and specificity. A set of weights are then associated with this criterion hierarchy to indicate the importance of each criterion in relation to the others.

The underlying concepts of the approach for assessing the effectiveness of candidates are discussed in the following paragraphs. This discussion is presented in accordance with the breakdown of the effectiveness model into its constituent elements and includes guidelines for the development of each model element discussed.

Definition of Effectiveness and Associated Implications

The approach for assessing the effectiveness of candidates and the development of the effectiveness model which forms the basis for this assessment are closely related to the definition of effectiveness. In the context of this study effectiveness is not to be viewed as a fixed and preformulated expression in terms of some specific variables. Instead, the following definition of effectiveness is used:

- The effectiveness of a candidate is broadly defined as its overall quality. This quality is determined on the basis of how well the candidate fulfills specified objectives, requirements and constraints. Furthermore, this overall quality can be quantified and the resulting number is the effectiveness rating of the candidate. The effectiveness rating is a quantitative measure of the degree to which the candidate has satisfied the aggregate of all the individual criteria for determining conformance with objectives and requirements as well as their relative importance.

It is noted that the above definition of effectiveness implies the following:

- It is necessary to specify objectives, requirements and constraints.
- It is necessary to establish criteria for judging how well the candidates fulfill the objectives, requirements and constraints.
- It is necessary to indicate the importance of the established criteria relative to one another.

- It is necessary to quantify each individual criterion as well as the aggregate of all criteria and their relative importance. This quantification must be based on candidate attribute data (i.e., characteristics).

The development of the effectiveness model forms the basis for accomplishing the above objectives.

Elements of the Effectiveness Model

As noted in the previous discussion the development of the effectiveness model is the basis for assessing the effectiveness of candidate system/vessel combinations. Completion of the effectiveness model also provides the basis for developing the required effectiveness attribute data as well as for quantifying effectiveness.

The effectiveness model consists of the following elements:

- Measures of Effectiveness (M/Es)
- M/E weights
- Factors and subfactors of the M/Es
- Factor/subfactor weights
- Effectiveness Rating Functions (ERFs) for the elementary factors/subfactors

Each one of the above elements of the effectiveness model is discussed in the following paragraphs. Guidelines for developing each model element are also given. In addition, the nature of the necessary effectiveness attribute data and the procedure for quantifying effectiveness are also discussed.

SELECTING MEASURES OF EFFECTIVENESS (M/Es)

Purpose and Definition of M/Es

Candidate systems for a given vessel class can be compared more readily if a numerical score for effectiveness is determined for each candidate. As a first step in the process of quantifying effectiveness, it is necessary to establish a set of Measures of Effectiveness (M/Es). The M/Es constitute the figures of merit or the set of overall criteria which will be used to judge how well each candidate system meets the requirements which are deemed to be important. M/Es are broadly defined considerations or realms of concern for the decision maker.

Required Properties of M/Es

A valid set of M/Es should be characterized by the following properties:

- Appropriate level of comprehensiveness
- Completeness
- Uniqueness and independence

Appropriate level of comprehensiveness implies that each M/E selected is sufficiently general to encompass or imply all the pertinent subcriteria which will subsequently be identified (the factors and subfactors). As an example, the number of man-hours required would not be an appropriate M/E since it is implied or encompassed by (and hence is subordinate to) another (and more general) figure of merit such as Operability or Maintainability.

Completeness implies that the M/Es selected (together) encompass all aspects which are considered to be important, i.e., they are, as a group, capable of assessing the candidate's qualifications with respect to all relevant criteria.

Uniqueness and independence implies that none of the characteristics which are implied or included in one M/E appear in any one of the other

M/Es, i.e., there is no overlap in the various criteria (factors and subfactors) which are implied by the selected set of M/Es.

Guidelines and Considerations in Choosing M/Es

When selecting a set of M/Es, it is important to keep in mind that these M/Es are not intended to be a universal and all encompassing set of figures of merit which are adequate for any conceivable set of circumstances. Instead, the M/Es should be based on the basic objectives and requirements at hand for the specific candidate system/vessel combination being studied. The following considerations should govern the selection of M/Es:

- It is not necessary to decide in advance (or to know the details of) how each M/E will subsequently be broken down into its constituent factors and subfactors in order to choose an adequate set of M/Es. In fact, different individuals can be involved in these two processes.
- Each M/E should represent an inherently different set of considerations or criteria.
- They should be as few as possible in number, consistent with the goals of the study. No M/E should be included unless it is determined to be an essential consideration in assessing the effectiveness of the candidate systems. A proliferation of M/Es decreases the sensitivity of the overall effectiveness score for each M/E. Also, a multitude of M/Es makes it more difficult to make balanced judgements in assigning weights to the M/E. The number of M/Es used should be limited to less than ten.
- A figure of merit which is a potential candidate for an M/E should not be eliminated from consideration on the basis of the argument that this M/E is not necessary because there are rigid requirements governing this area of concern which will take care of this problem. As an example, one may be tempted to argue that

"Safety" should not be made an M/E because there are specific regulations governing safety and an unsafe system will not be permitted to be installed on board a ship. The fallacies of such an argument are as follows:

- The fact is that irrespective of rigid specifications, unsafe equipments are to be found on board ships and accidents do occur.
- If the above argument is pursued to its logical conclusion, then all M/Es would be eliminated from consideration since there are also specifications for performance, reliability, habitability, operability, etc.
- Even if all candidates met the safety specifications (these can be considered as a minimum requirement), there are nevertheless substantial differences among candidates in the degree of safety and these differences should be identified and quantified.

- It is usually easier to eliminate or add an entire M/E than it is to make numerous changes within several M/Es.
- The relative importance or unimportance of each M/E will be stipulated via the weight assignment scheme.
- The utility and ease of interpretation of the final results, i.e., the overall effectiveness score of each candidate system, will depend (among other things) on the care with which the M/Es and their weights are selected.
- The wording used to describe an M/E should be concise and carefully chosen to ensure that the full meaning and all the criteria implied by the M/E are reflected in its name. A short statement of the issues implied by each M/E should be provided.

ASSIGNING WEIGHTS TO THE M/Es

Purpose of M/E Weights

Assignment of weights to the M/Es serves two essential purposes. First, these weights enable the decision maker to reflect his judgement as to the relative importance of each M/E, based on the candidate systems and the vessels being considered as well as the objectives and goals of the study. Thus, the M/E weights provide the decision maker with the opportunity to perform trade-offs between the different considerations governing the selection of a candidate system.

Second, assignment of weights to the measures of effectiveness facilitates the combination of the individual M/E ratings into an overall effectiveness rating for each candidate.

Guidelines for Assigning M/E Weights

Since the choice of weights has a strong influence on the overall effectiveness rating of the candidates and therefore influences the manner in which they will be ranked, the choice of M/E weights should be made by cognizant decision makers who are familiar with the considerations which were used to determine the specific choice of M/Es. Due to the importance of these M/E weights, great care should be exercised in their selection. Following are some guidelines for assigning M/E weights.

- All of the subordinated levels of factors and sufactors within the effectiveness model structure do not have to be identified in order to assign M/E weights.
- Weight assignments are to be system and vessel independent (knowledge of system or vessel characteristics is not required).
- Weight assignments are to be used to convey the importance of each M/E relative to one another.

- Weight assignments are to indicate importance by assigning higher numbers to those M/Es that are more important and low numbers to those of lesser importance.
- Numbers should be assigned on a percentage basis (whole numbers only) and should range on a scale of 0-100%, with the sum of all weight assignments equal to 100%, i.e.,

$$W_1 + W_2 + W_3 + \ldots\ldots W_m = \sum_{i=1}^{m} W_i = 100$$

DETERMINING THE FACTORS AND SUBFACTORS OF EACH M/E

Each M/E encompasses a large number of considerations and hence depends on a multitude of candidate system attributes. As a result, it is not practical to attempt to obtain a direct rating for each candidate system with respect to the M/Es. Instead, each M/E is systematically broken down into its constituent component criteria and then a relationship between each of these component criteria and the candidate system's attribute is established.

Selecting Factors of an M/E

As a first step in this breakdown, a set of factors is selected to characterize each M/E. These factors, in combination, represent all the aspects or attributes of a candidate system which are considered to be relevant to the particular M/E. The set of M/E factors is not necessarily unique. In establishing such a set, it is important to ascertain that they are characterized by the following properties:*

- Appropriate level of comprehensiveness
- Completeness
- Uniqueness and independence

* It is noted that these properties were also called for in the choice of the set of M/Es.

The first property is concerned with picking a set of factors which represent, in effect, a first indenture of each effectiveness measure, rather than a set of very detailed considerations which would be appropriate only at further levels of indenture. As an example of what is meant here, "special tool requirements" is an appropriate consideration which is implied by the M/E "Maintainability", but it would not be appropriate as a factor of this effectiveness measure because it is a consideration which is implied by the more general, and hence more appropriate, factor "Corrective Maintenance Requirements".

The second property is concerned with ascertaining that the factors chosen together constitute (i.e., imply) all aspects of the effectiveness measure which are considered to be important and relevant for that M/E. That is, the factors of an effectiveness measure must be capable of completely describing and characterizing it.

The third property is concerned with avoiding overlap in considerations which are implied by the different factors of an M/E, and to insure independence among factors, i.e., the rating of one factor is independent of the rating of any other factor.

Selecting Subfactors and Elementary Factors/Subfactors

The factors themselves may be too complex to assign ratings to them because they encompass a multitude of considerations. As an example, the factor "Corrective Maintenance Requirements" of the M/E "Maintenance" includes considerations such as labor, parts, accessibility, etc. The procedure which is followed in such cases is to break up each complex factor into a set of subfactors which, together, encompass all the considerations which are implied by the factor. In choosing a set of subfactors for each factor, the same considerations which govern the choice of factors for each M/E are employed, namely:

- Appropriate level of comprehensiveness
- Completeness
- Uniqueness and independence

Often, subfactors may themselves be too complex because they imply numerous considerations and hence may require further breakdowns. This is accomplished by determining a set of lower level subfactors for each complex subfactor. The procedure employed is analogous to those used for determining the factors of each M/E, as well as those for choosing the subfactors of a complex factor, and the same criteria apply. This procedure of breaking down a complex subfactor into a set of lower level subfactors is continued successively as many times as necessary or convenient until a set of elementary subfactors (or factors) is reached. An elementary subfactor or factor is one which encompass a single consideration and hence can be rated by relating it to some attribute of the candidate system. As an example, "Accessibility of replaceable components" is an elementary subfactor of the subfactor "Ease of repair/replace", of the factor "Corrective Maintenance requirements", of the M/E "Maintainability". This is a single aspect of maintainability for which a direct relationship can be established between the magnitude of the candidate system attribute and a numerical rating for the elementary subfactor.

It is noted that the choice of elementary subfactors/factors is not always obvious or unique. As an example, the number of maintenance man-hours required may be chosen as an elementary subfactor. However, several maintenance personnel, at different skill levels may be assigned to the system/equipment whose maintainability is being analyzed. The question arises, then, whether the maintenance man-hour requirement should be further broken down by skill level or whether the sum of man-hours for all skill levels is sufficient. The decision on the extent of breakdown and therefore the level of the analysis depends upon a number of considerations, including the availability of data and the funding as well as the time available for the analysis.

Unique Identification of Factors and Subfactors

The levels of subordination of factors and subfactors are conveniently indicated by successive indentures and by the number of "bullets" appearing

in front of the factor or subfactor. Elementary factors/subfactors are those having the largest number of such "bullets" in front of them.

Usually, there are more than one factor or subfactor at any given level of subordination. In order to form a unique identification of each factor and subfactor, a numbering scheme is used as follows:

- The number of digits indicates the level of subordination of the factor or subfactor.
- The first digit represents the factors, the second digit represents the subfactors, the third digit represents subfactors of subfactors, etc.
- The numerical value of each digit represents the sequence or position of the corresponding factor or subfactor in relation to the others at the same level from top to bottom, starting with 1 for the first, 2 for the second, etc.
- Since the number of factors or subfactors at any given level of subordination will be limited to nine, the digits will range from 1 to 9. As a result, it is not necessary to have any separators between the digits in the number which designates the unique identifier for a given factor or subfactor.

ASSIGNMENT OF FACTOR/SUBFACTOR WEIGHTS

Purpose of Factor/Subfactor Weights

After the effectiveness measures are broken down into factors and subfactors and their associated levels of subordination, it is necessary to assign weights at each level of subordination. These weights serve two essential purposes. First, they provide a means of combining the ratings for the factors and subfactors in order to obtain an overall numerical rating for each effectiveness measure. Second, they provide an opportunity for the analyst to specify how much each factor and subfactor is to contribute to the effectiveness rating within each effectiveness measure. This compliments the level structure of the effectiveness model, which shows the

breakdown of each measure of effectiveness into factors and successive levels of subfactors to indicate the manner in which the various criteria are related to one another in terms of subordinate levels of considerations. On the other hand, weights indicate how important each consideration is in relation to the others. Thus, the factor and subfactor weights allow the decision maker to perform trade-offs between relevant considerations.

Guidelines for Assigning Factor/Subfactor Weights

The approach for assigning factor and subfactor weights is similar to that used for assigning weights to the effectiveness measures. The basis for the weight assignment is subjective judgement guided by experience and knowledge of the candidate systems, the vessels and the objectives of the study. Weight assignments should be made in consultation with individuals most familiar with the pertinent criteria under consideration, i.e., the factor/subfactors of each M/E. Following are some guidelines for assigning factor/subfactor weights.

- Weights are assigned to each effectiveness measure systematically in a step-by-step manner, following the factor/subfactor level of subordination structure, beginning with the highest level, i.e., the factors of the effectiveness measures.
- Weights are assigned on a per level basis i.e., the distribution of weights among the factors or subfactors at a given level should not be influenced by the weights already assigned or those to be assigned to factors and subfactors at higher or lower levels.
- Weights are distributed to factors or subfactors at the same level on the basis of the importance of each factor or subfactor in relation to the others. The degree of importance is indicated by the numerical value assigned to the factor or subfactor weight, following the convention that a higher weight means greater importance and a lower weight means less importance.

- The numerical value of the factor/subfactor weights are given as a percentage on a scale from 0 to 100% (given to the nearest percentage point).

- Weights must be distributed among the factor/subfactors at the same level, taking relative importance into account, so that the sum of the weights at any given level is equal to 100, i.e.,

$$W_1 + W_2 + W_3 + \ldots, W_n = \sum_{i=1}^{n} = 100$$

- Factor/subfactor weights are system independent but may be vessel dependent, i.e., the distribution of weights at any given factor/subfactor level may be different for each vessel. This enables one to accommodate the fact that some considerations may be more important on one vessel than on another vessel.

DEVELOPMENT OF EFFECTIVENESS RATING FUNCTIONS (ERFs)

Purpose and Definition of ERFs

Having developed the structure of the effectiveness model, (consisting of a breakdown of each Measure of Effectiveness (M/E) into its factors and subordinate subfactors) and having assigned weights to the M/Es and to all factors and subfactors, it is necessary to determine a numerical effectiveness rating for the elementary factors/subfactors for each viable candidate system vessel combination in order to quantify each M/E as well as the overall effectiveness. Determination of numerical effectiveness ratings for each elementary factor/subfactor consists of the following three steps:

- Development of an effectiveness rating function (ERF) for every elementary factor/subfactor within each M/E.
- Development of effectiveness attribute data for every viable candidate system/vessel combination, as required for input to each effectiveness rating function.
- Use of the effectiveness attribute data for each viable candidate system/vessel combination as input to the effectiveness rating functions to obtain an effectiveness rating for every elementary factor/subfactor.

An effectiveness rating function establishes a generic relationship between a relevant quantitative or qualitative system/vessel characteristic, i.e., the "value" of the system/vessel attribute, and a numerical rating which expresses a subjective judgement of the "worth", "quality", desirability, adequacy, acceptability, preference, etc., of the attribute "value". The rating is a subjective indicator of how well each candidate fulfills (on a relative basis) the criterion established by the relevant elementary factor/subfactor. This is to be distinguished from the factor/subfactor weights which indicate how important (on a relative basis) each

criterion is. Establishment of the effectiveness rating functions constitutes the final step in the development of the effectiveness model. After this step has been completed, the quantification of effectiveness becomes a straightforward, although tedious, procedure which readily lends itself to computer implementation.

Steps in the Development of ERFs

Since the effectiveness rating functions (in conjunction with the M/E and factor/subfactor weights and levels of subordination) form the ultimate basis for quantifying the effectiveness of each viable candidate system/vessel combination, great care should be exercised in their development. The derivation of effectiveness rating functions requires a clear and thorough understanding of the criteria which are implied by the relevant elementary factors/subfactors, knowledge of the candidate system/vessel characteristics (attributes) and the manner in which they are "measured" as well as the ranges of "values" of the attribute data, and the use of subjective judgement as to what constitutes "good" and "poor" attribute "values" for candidate system/vessel characteristics. The development of effectiveness rating functions consists of the following three basic steps:

- Determine the system/vessel characteristic which will serve as the effectiveness attribute variable to be used as a "measure" of the criterion implied by the relevant elementary factor/subfactor. This step may entail an intermediate step which combines two (or more) different types of raw system/vessel characteristics, e.g., the use of skill weighted man-hours as a measure of the burden on the vessel crew for system operation and maintenance, or the use of system weight and its location within the vessel to determine the moment as a measure of the effect on vessel stability, trim or list. Effectiveness attribute variables may be system dependent only (e.g., odor, noise, etc.) or system and vessel dependent (e.g., moment). System/vessel attribute variables may be quantitative (e.g., dimensions in feet, number

of man-hours required for operation/maintenance, the number of different spare part types required) or they may be qualitative (e.g., odor or noise produced by system, complexity of system). Quantitative effectiveness attribute variables may be continuous (e.g., weight of system, consumption of fuel, etc.) or they may be discrete (e.g., the number of skill levels required for operation/maintenance, the number of duplicate systems required, etc.).

Determine the format, i.e., form and shape, of the functions to be used in relating "values" of the effectiveness attribute variable on the horizontal axis to rating numbers on the vertical axis which are a measure of the "worth" or degree of "goodness", the "desirability", etc., of the corresponding "value" of the attribute variable. This step requires the use of subjective judgement to determine what constitutes "good" and "poor" "values" for the pertinent system/vessel attribute variable. It also requires determination of the "rate" at which changes in attribute values are to be "rewarded" or "penalized", i.e., it requires that a rating number be assigned to every possible "value" of the attribute variable. The ratings are numerically expressed as a percentage, on a scale ranging from 0 to 100%, using the convention that a high rating represents a favorable condition and a low rating represents an unfavorable condition (i.e., an undesirable value of the attribute variable).

Determine the "limits" ("upper" and "lower") of the rating function. This is based on subjective judgement of what constitute "acceptable" and "unacceptable" system/vessel "values" for the attribute variable.

Criteria and Guidelines for Developing ERFs

The development effectiveness rating functions is, to a large extent, an art and as a result the quality of the rating functions is dependent on the ingenuity, creativeness and resourcefulness of the analyst. It is noted that this also applies to the development of the structure of the effectiveness model. As a result, a step by stop systematic procedure for formulating effectiveness rating functions cannot be given. Instead, guidelines and assessment criteria for the development of effectiveness rating functions will be given.

Following are some criteria for judging the quality of an effectiveness rating function. An elegant rating function is characterized by the following qualitites:

- It directly addresses the intended criterion and encompasses all the issues implied by the elementary factor/subfactor.
- It is simple, i.e., the rating procedure is transparent (visible) to the reader without resorting to elaborate explanations, and the reader can relate to it readily (i.e., the reaction is that it is "obviously" the way to do it, after he sees how it was done).
- It highlights and emphasizes differences and suppresses similarities between candidate system/vessel combinations.
- It is consistent with the effectiveness attribute data availability, i.e., it does not require data which are not readily available and makes use of all pertinent data which can readily be obtained.
- It has a relatively high degree of repeatability (with respect to time and across individuals), especially for subjective criteria.

Following are some guidelines for developing effectiveness rating functions for elementary factors/subfactors.

- It is not necessary to be familiar with the details of the structure of the effectiveness model, or the associated M/E and factor/subfactor weights, in order to formulate cogent rating functions.
- It is not necessary to have the actual system/vessel attribute data available in order to formulate the concept and general shape of the effectiveness rating function. However, full definition of a rating function may have to await determination of the effectiveness attribute data for all viable candidate system/vessel combination in order to fix limits, ranges, extreme points, function shape, etc.
- The purpose of effectiveness rating functions is to measure "how good" a system/vessel characteristic is. Rating functions are not concerned with "how important" that characteristic or feature is (this aspect is handled by the factor/subfactor weights).
- Effectiveness rating functions for elementary factors/subfactors should be structured such that a higher numerical rating means "better", "more favorable", "more adequate", etc., and a lower numerical rating means "worse", etc.
- Ratings of elementary factors/subfactors (i.e., the result of substituting system/vessel effectiveness attribute data into a rating function) will be expressed as a percentage ranging from 0 to 100%. Ratings should be given to the nearest percentage point.
- Effectiveness rating functions are always system dependent and may or may not be vessel dependent too.
- Ideally, effectiveness rating functions which measure consumption of vessel resources (fuel, electric power, space, man-hours, etc.) should be related (normalized) to vessel capacity, rather than using a normalization scheme based on the maximum value.

- Vessel dependence of an effectiveness rating function can be handled by one of the following methods:
  - Prepare separate curves for each vessel or show a family of curves on the same set of axes with the vessel as the parameter.
  - Use a generalized effectiveness attribute variable which incorporates the vessel dependence in it (e.g., WMS electric power consumption expressed as a percentage of the whole or a fraction of the vessel generating capacity).
  - Use an effectiveness attribute variable which incorporates the vessel dependence as an explicit parameter to be entered when evaluating a given system/vessel combination, i.e., the actual position of a given system/vessel combination on the attribute scale becomes fixed when the vessel parameter (in addition to the system attribute value) is substituted.
- Effectiveness rating functions should be consistent with the availability of system/vessel effectiveness attribute data, it should utilize the data which is readily available to the maximum extent but should not place an undue burden on data requirements by specifying data which is either unavailable or is impractical because it requires an unwarranted effort or expense to obtain.
- An effectiveness attribute variable may itself be a function of other raw system/vessel attribute variables (e.g., weighting man-hours by skill level to obtain a skill weighted labor requirement, etc.).
- A primary purpose of effectiveness rating functions is to highlight differences between system candidates rather than to show similarities. This should be taken into account when structuring rating function shapes, establishing ranges, extreme points, etc.

- In rating certain undesirable attributes, consideration should be given to system/vessel conditions which facilitate easy elimination or alleviation of the problem (e.g., better ventilation to remove odor and heat, better shock mounts to reduce vibration, etc.) by "penalizing" such system/vessel combinations less than those which do not have this property.

- Effectiveness rating functions which depend on subjective judgements should take into account the tendency of most people to provide answers which tend toward the average. This can be counteracted by providing many response choices at the extremes (good/bad, high/low, much/little) and few at the midpoint or average.

- Difficult (conceptually or otherwise) effectiveness rating functions are probably best done in stages rather than investing a lot of time trying to formulate it during the first attempt.

- Effectiveness rating functions and the form of the required attribute data should be transparent (visible) to the reader. If intermediate steps are used to convert the necessary raw attribute data to the required format, these steps should be clearly indicated. Unless there are compelling or overriding considerations, rating function shapes should be simple curves (a shape which is readily "understood" by the reader). Examples of overriding considerations which would warrant more complicated rating function shapes is a priori knowledge that the effect under consideration is a non linear function (i.e., it varies as the square, the square root, exponentially, etc.) of the attribute variable. Such a non linear functional relationship may also be used to "penalize" or "reward" a candidate system/vessel combination which has "good" or "poor" values for the attribute variable.

Some Examples of ERFs

Examples of possible effectiveness rating function shapes are shown in Figure 5. The functions represented by (a), (b), (c) and (d) in Figure 5 are for effectiveness attributes which are continuous variables. The functions represented by (e) and (f) are for attributes which are either discrete variables or for continuous variables for which ratings are more readily assigned to ranges of the variable instead of to every possible value of the variable. The functions represented by (g) and (h) are for attribute variables whose "values" are not numerical but represent either qualitative information or yes/no answers to specific questions. Functions represented by (a), (b), and (e) are such that the higher the value of the attribute variable, the lower the rating and vice versa, i.e., low values of the attribute are favorable and high values are unfavorable (e.g., total man-hours required for maintenance, the total number of different skill levels required). The functions represented by (c), (d) and (f) are such that the higher the value of the attribute variable the higher the rating and vice versa, i.e., high values of the variable are favorable and low values are unfavorable (e.g., MTBF of an equipment). Functions (a) and (c) are representative of attribute variables which have an upper limit, whereas functions (b) and (d) are representative of variables which do not have an upper limit. It is noted that an attribute variable may inherently not have an upper limit yet be represented by a function which shows an upper limit. An example of such a situation is an attribute variable such as total maintenance man-hours which has been normalized by dividing the value for each candidate either by the highest value or by a fraction of a year or by the vessel complement (or fraction thereof). The value used for normalization thus becomes the upper limit. Function (g) is representative of an attribute variable which is qualitative in nature and the "values" of the variable are degrees of "goodness" in comparison to some specified standard (e.g., the odor level generated by the WMS fixtures, in comparison to standard household fixtures). Function (h) represents an attribute variable whose "values" are yes/no answers to a specific question (e.g., "are special tools required?").

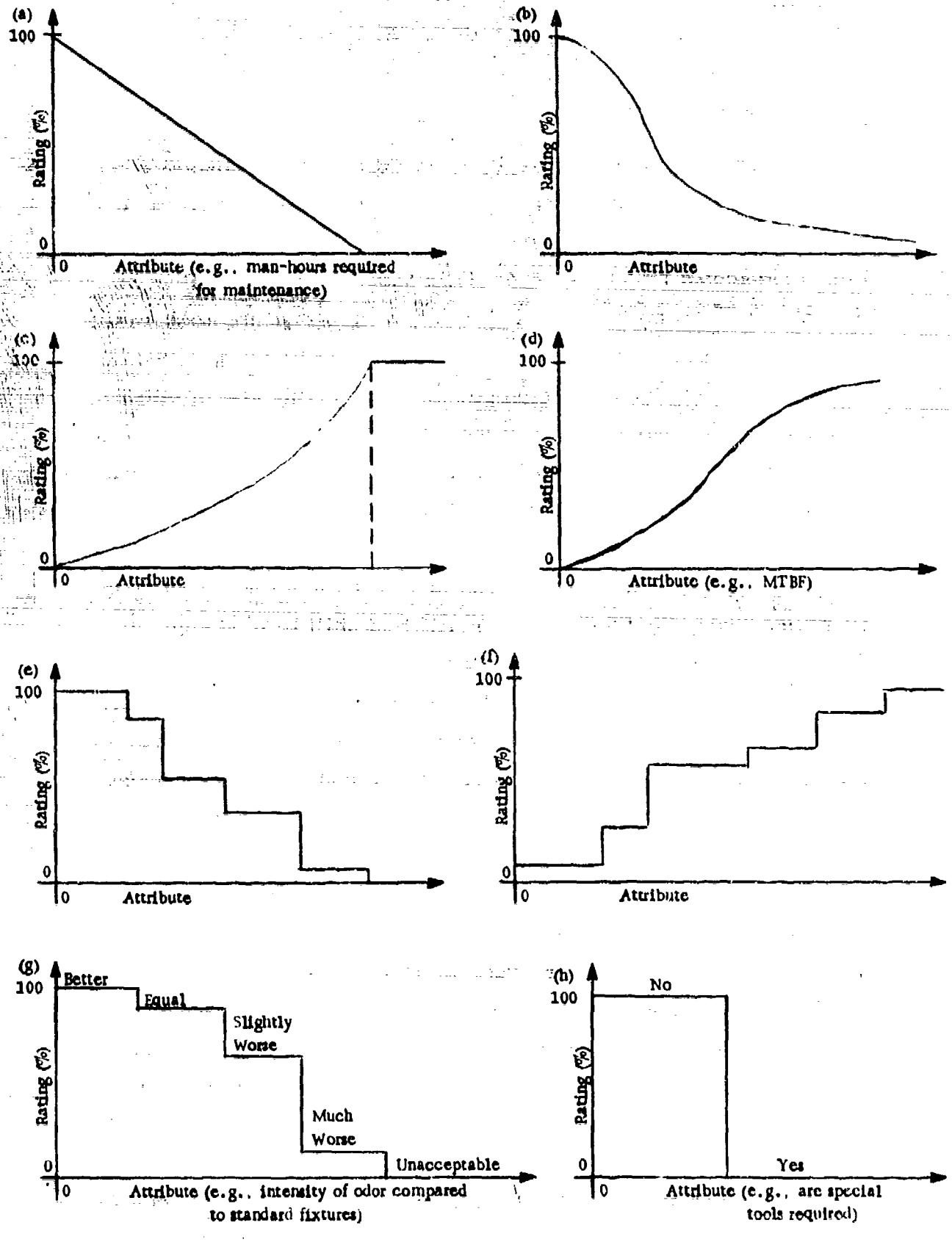


Figure 5

EXAMPLES OF EFFECTIVENESS RATING FUNCTION SHAPES FOR ELEMENTARY FACTORS/SUBFACTORS

The sample functions presented in Figure 5 are suggestive of the procedures used for rating elementary factors/subfactors. The actual functions to be used in any given problem have to be determined by the analyst on the basis of his familiarity with the candidate system/vessel combinations involved, the data available, his experience and judgement.

Further examples of effectiveness rating functions are provided in Figure 6 which shows ratings of some automobile characteristics which may be of interest to some users. The function in (a) attempts to rate automobile fuel economy. This rating function indicates that an automobile getting less than 5 miles/gallon is considered to be unacceptable (a rating of 0%), whereas an automobile which yields 40 miles/gallon or more is considered to have the maximum rating of 100%. Automobiles which have fuel economies within the range of these two extremes are rated on a linear scale sloping from 0 to 100%. The functions in (b), (c), and (d) for rating automobile range, stopping distance and acceleration, respectively, are based on the same principle. The rating function in (e) for rating handling and steering are subjective estimates based on comparison to an implied standard, in this case, the "average" of all automobiles. The rating function in (f) for arrangement and labeling of instruments is based on an absolute (as opposed to comparison) qualitative subjective estimate. The rating function in (g) for safety features such as the existence of reinforcement or a collapsible steering column is a two valued (0 or 100%) rating function based on the answer to a yes or no question.

"Difficult" ERFs and Repeatability

It is recalled that an elementary factor or subfactor is one that encompasses a single consideration or criterion and hence can be rated by relating it to some characteristic or attribute of the candidate system/vessel combination. However, there are circumstances in which the formulation of a rating function, which requires subjective assessment of the attribute, is complicated by the fact that the elementary factor/subfactor depends on

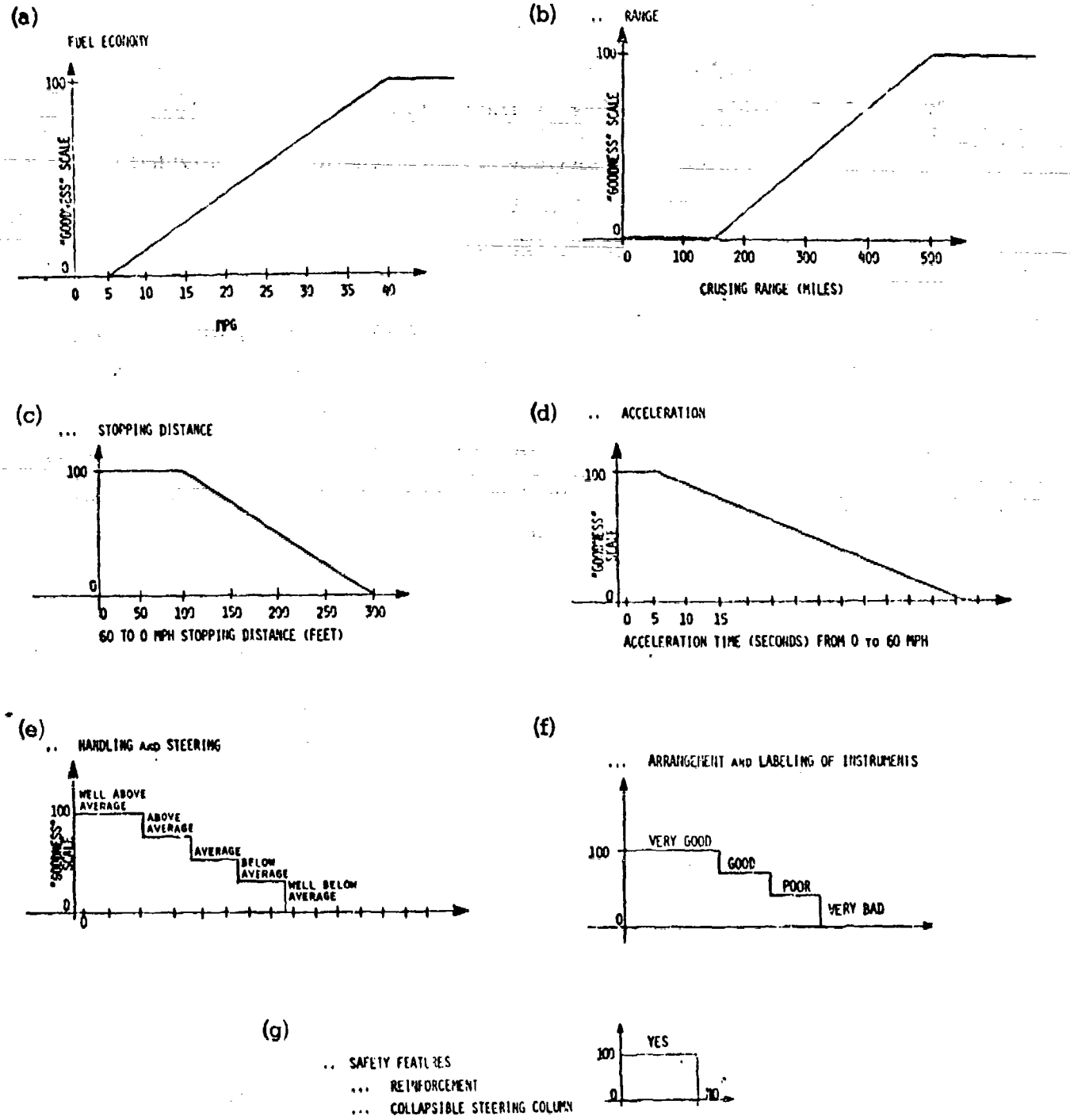


Figure 6

EXAMPLES OF EFFECTIVENESS RATING FUNCTIONS
FOR AUTOMOBILE CHARACTERISTICS

more than one variable (e.g., the effect of foreign objects based on a lengthy list of objects), or the data available for a single variable is elaborate.

An example of such a circumstance is presented in Figure 7 which provides data on automobile frequency of repairs, broken down by subsystem. The frequency of failures for each automobile function or subsystem is given as one of five possible levels or degrees and are designated by circles which are either blank or have in them crosses, slashes, partial and full shading. Note that one would find it difficult to use this information directly to rank the automobiles with respect to reliability, especially when a fair number of candidate automobiles are involved. It is further noted that even if one were somehow able to rank the reliability of the automobiles at a given time, the repeatability of such a ranking, even by the same individual, at a later time would be relatively poor. Finally, it is noted that even if one somehow managed to rank the automobiles on the basis of reliability so that a given candidate is more reliable than another candidate, one would find it extremely difficult to answer the question by how much?

Before proceeding to a proposed approach for developing effectiveness rating functions for situations of this type, it is worthwhile to examine what makes this example (and others similar to it) "difficult". The problem is that there are subjective elements and many mechanical elements and the usual thought process is such that the two are intermingled and decisions are made on the basis of an unclear mix of the two. Hence, the reason for poor repeatability because the mechanical elements, although simple, may be numerous and therefore overpower the subjective elements, although they may be few in number. In the above example, the subjective elements are the relative importance of each subsystem and the "worth" of each level of frequency of failure. The mechanical element is the "count" of the number of symbols of each type for a given candidate automobile.

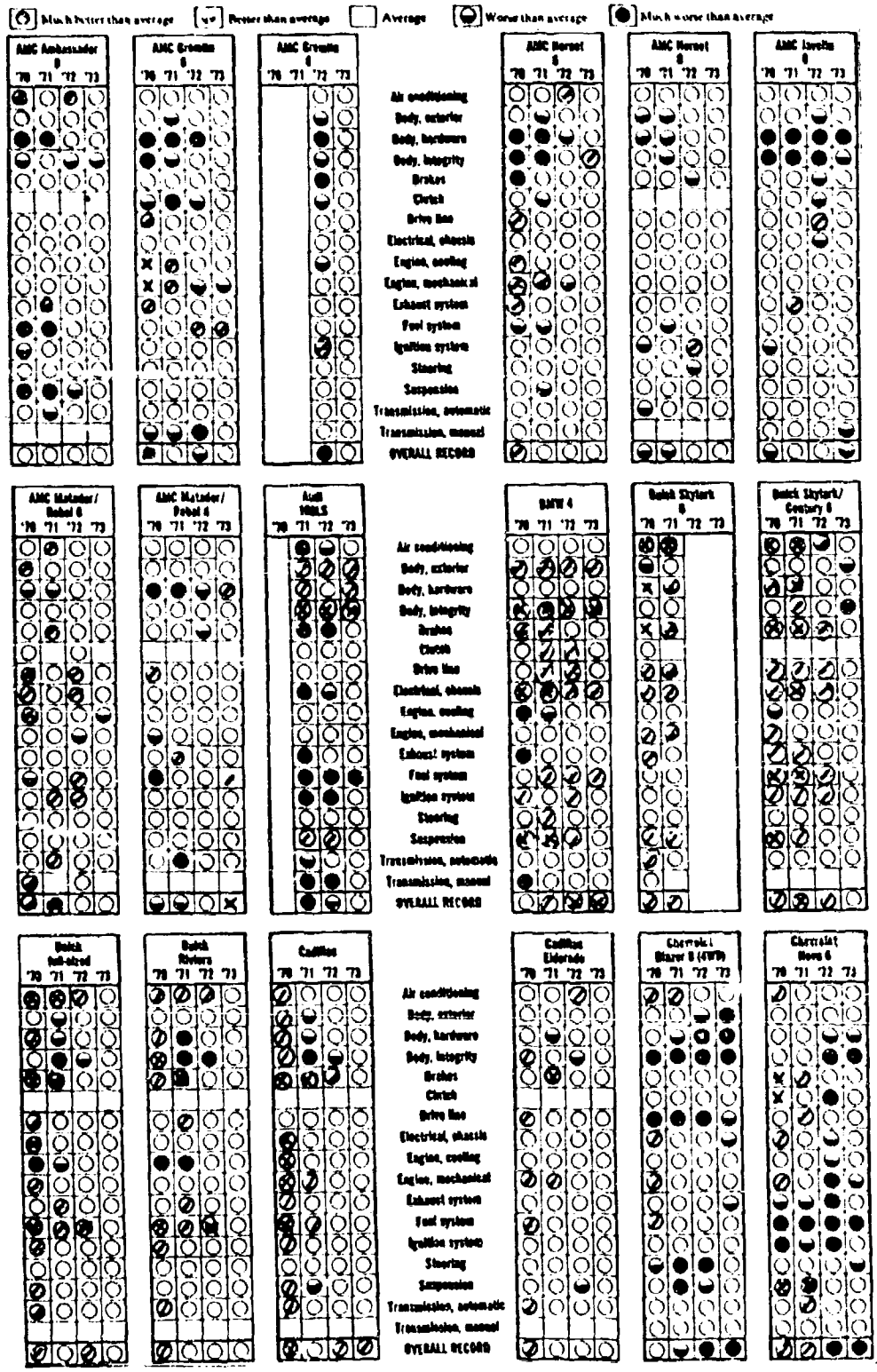


Figure 7

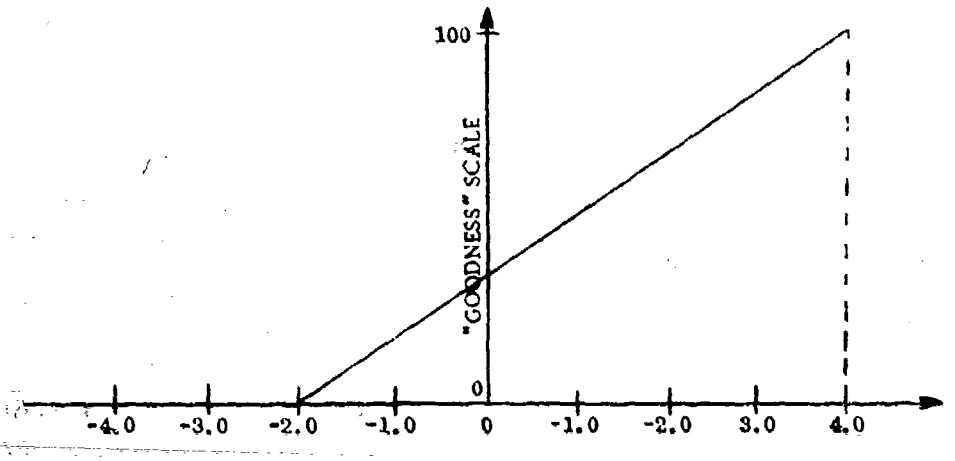
FREQUENCY OF REPAIR RECORDS FOR AUTOMOBILES

The solution to the problem of formulating effectiveness rating functions for "difficult" situations of this type is to proceed as follows:

- Identify and separate the subjective and the mechanical aspects clearly and concisely.
- Carefully pinpoint and study the subjective elements and make judgements relative to these elements only. Carefully document these judgements and the reasoning behind them, if any.
- Develop a numerical procedure for systematically combining the subjective and the mechanical elements to yield a rating for a given candidate.

An example of the application of the above principles to formulate an effectiveness rating function for automobile reliability based on failure frequency data is presented in Figure 8. It is noted that the effectiveness rating function in Figure 8 is based on the following subjective judgements:

- The "importance" (on a relative basis) of each subsystem (W_i).
- The "worth" (D) of each possible reported ranking of failure frequency, i.e., much better than average (⊗), better than average (Ø), average (O), worse than average (⊖), much worse than average (●).
- The "range" of acceptable values for the attribute variable, which was chosen to be a Record of Repair Index (R) obtained as the sum of products of the importance (W_i) and the "worth" (D_i) of each subsystem for each year of reported data. This "range" was obtained by choosing a "minimum acceptable" value for R of -2.0 (from a possible "lowest" value of -4.0) and the maximum possible value for R of +4.0, which is considered to be "ideal". A linear relationship was chosen for rating candidate automobiles whose Record of Repair Index (R) falls in between these two limits.



Record of Repair Index (R)

$R = \sum_i W_i D_i$, where

i - Subsystem identification

D_i - Reliability of subsystem i based on repair record. D_i takes on discrete values from +1.0 to -1.0 in steps of .5, based on repair record as follows:

Symbol		D	Interpretation
⊗	CROSS	+1.0	Much better than average
⊘	SLASH	+0.5	Better than average
○	BLANK	0	Average
◒	BLACK	-0.5	Worse than average
●	BLACK	-1.0	Much worse than average

W_i - Weight (importance) of subsystem i. The values of W_i are chosen so that

$$\sum_i W_i = 1.0 \ (100\%)$$

Figure 8

EFFECTIVENESS RATING FUNCTION FOR AUTOMOBILE RELIABILITY

It is noted that once the above subjective judgements have been made, together with the definition of the attribute variable (the Record of Repair Index, R) the rating of the reliability for any given candidate automobile is not only purely mechanical, straightforward and systematic but it is also perfectly repeatable. It is suggested that the overall repeatability of the ratings, with the inclusion of the subjective elements, is much higher with the use of this approach than it would be without it, i.e., on the basis of a direct visual comparison of the failure frequently data for each automobile. Furthermore, the above scheme for rating automobile reliability not only ranks the candidates with respect to reliability, but it also indicates "by how much" one candidate is "more reliable" than any other candidate on a relative basis, which results from using the same rating procedure for each candidate.

A final comment on the above example involves the treatment of missing data. The amount of data available may not be the same for all candidate automobiles. This may be due to the fact that some models may have been introduced during the years for which failure frequency data was collected, or insufficient data may be available for some models or for some of the subsystems of some models due to inadequate user response. Since the value of the attribute variable, the Record of Repair Index (R) must be based on the same amount of data for all candidates in order for it to have a consistent interpretation with respect to relative magnitudes, it is necessary to fill in the "missing" data (whether real or artificial). The procedure which may be adopted for filling in missing data depends on one's attitude toward data which is unavailable. That is, one can be an optimist and assume that if the data were available, it would be favorable, or use the argument that since the facts are not known it is "unfair" to assume that the data would tend to penalize the system. On the other hand, one can be a pessimist and assume that if the data were available, it would be unfavorable, or use the argument that unavailability of data is as bad as available unfavorable data since the decision has to be made now and

cannot be deferred until such time that data does become available. Another possible approach, perhaps in between the above two extremes, is to use some procedure which fills in the missing data with the "average" of the available data. If the missing data is for one or more entire year then one can determine a value of R based on 2 or 3 years and apply a scaling factor (of 2 or 4/3) to convert it to an equivalent R based on 4 years of data.

Simplified ERF's Based on Ranking

The procedures described above for rating elementary factors and subfactors may not be practical in certain situations due to one of the following reasons.

- Quantitative data is not available.
- A simpler and quicker rating procedure is warranted due to the relatively high level of the analysis, e.g., during the early stages of the system life-cycle (such as during concept formulation).
- The unavailability of sufficient time and/or funding for a detailed analysis.
- The ratings are based on highly subjective attribute data which require difficult judgement.

Instead, a simplified rating procedure is desired.

The simplified elementary factor/subfactor rating procedure is based on a ranking of the candidates. This approach is relatively fast and simple to use, however, some accuracy is sacrificed. The procedure consists of two simple steps. First, the candidates are ranked with respect to the attribute, starting with one (1) for the "best", two for the "second best", etc. The elementary factor/subfactor rating (R) is then determined from the relationship

$$R = 100 \left(1 - \frac{i}{n+1}\right), \text{ where}$$

i = Rank of the candidate

n = The total number of candidates

In order to illustrate the use of the rating procedure based on a ranking of candidates and to point out the associated loss of accuracy, consider the following example. The effectiveness of three candidate systems is being evaluated for the effectiveness measure "Maintainability" in which one of the elementary subfactors depends on the system attribute man-hours consumed per year.

Assume that the three candidate systems (A, B and C) have the following values of this attribute:

System	Attribute (Man-Hours)
A	500
B	15
C	5

A ranking procedure, assuming that a lower man-hour requirement is more desirable, would assign the following ranks to the above systems:

System	Attribute (Man-Hours)	Rank
A	500	3
B	15	2
C	5	1

These rankings are then converted to effectiveness ratings in the range from 0 to 100% by the following relation:

$$\text{Rating (Man-Hours)} = \left(1 - \frac{[\text{System Rank (Man-Hours)}]}{4}\right) 100$$

The above relationship yields the following results based on ranking:

System	Attribute (Man-Hours)	Rank	Rating (Man-Hours) - %
A	500	3	25
B	15	2	50
C	5	1	75

These results indicate that the three systems are different and that System B is "better" than System A and that System C is "better" than System B. These conclusions are consistent with what one would expect based on an examination of the raw data presented. However, the results indicate an "equal" difference of 25% between Systems A and B, and between Systems B and C. This conclusion contradicts what is intuitively expected on the basis of the raw data.

To illustrate the type of results provided by a rating which is based on the absolute value of the attribute data rather than on a ranking, consider the simple rating scheme which subtracts the relative magnitude of the attribute (normalized by dividing each by 1000 man-hours) from 1.0, namely:

$$\text{Rating (Man-Hours)} = \left(1 - \frac{\text{Magnitude of Attribute (Man-Hours)}}{1000}\right) 100\%$$

The above evaluation scheme yields the following results:

System	Attribute (Man-Hours)	Rating (Man-Hours) - %
A	500	50
B	15	98.5
C	5	99.5

These results again indicate that System B is "better" than System A and that System C is "better" than System B. However, the results also indicate that the difference between Systems B and A is <u>much greater</u> than the difference between Systems C and B. This is more in accordance with the type of results which are intuitively expected on the basis of an examination of the raw data.

Comparison of the effectiveness ratings based on a ranking scheme with those based on the absolute value of the attribute data indicates the essential differences and similarities between these two methods of rating elementary factors and subfactors. Both methods are capable of answering the question:

which system is 'better'"? However, the conventional effectiveness rating scheme is also capable of answering the question: "By how much?", whereas the rating scheme based on ranking obscures degrees of difference between the condidates.

Simplified ERFs Based on Qualitative Assignments

The effectiveness rating functions discussed earlier are generally based on having either explicit quantitative system/vessel attribute data or qualitative/subjective data based on comparing all candidates to either a specified standard or to one another (ranking). A very simple type of effectiveness rating function can be formulated on the basis of absolute qualitative assignments based on subjective judgements. An example of such a rating function is presented in Figure 6 (f), which rates the adequacy of the arrangement and labeling of instruments in an automobile. The rating process simply consists of deciding for each candidate that the instrument arrangement and labeling is characterized best as very good, good, poor, very bad.

The procedure for formulating effectiveness rating functions based on qualitative assignments consist of two simple steps as follows:

- Choose a number of absolute qualitative levels or degrees of "goodness" to characterize the system/vessel attribute under consideration (e.g., excellent, good, acceptable, poor, unacceptable).
- Determine the "worth", on the rating scale, expressed as a percentage ranging from 0 to 100%, of each of the qualitative levels of acceptability chosen to characterize any candidate system/vessel combination.

It is noted that this approach for formulating effectiveness rating functions has the advantage of being quick and easy to develop. It may be used in a situation which requires a quick preliminary analysis when data

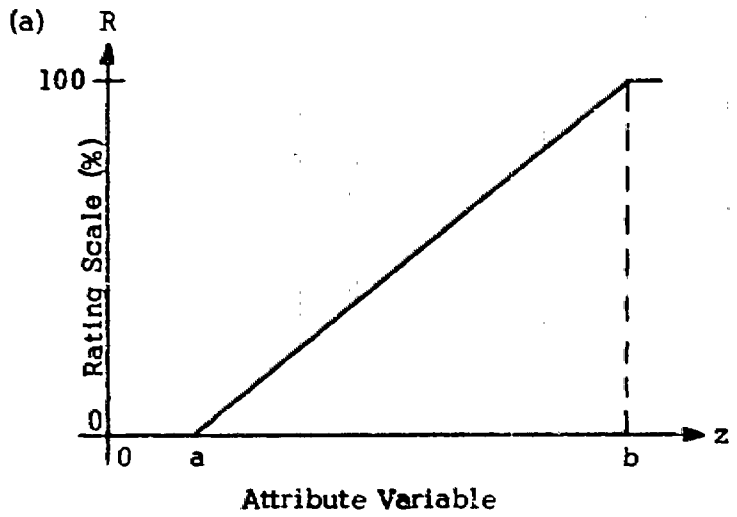
is either unavailable or the effort to obtain it is not warranted. This procedure may also be warranted when the attribute data, even in the context of a detailed analysis, is inherently qualitative and/or highly subjective.

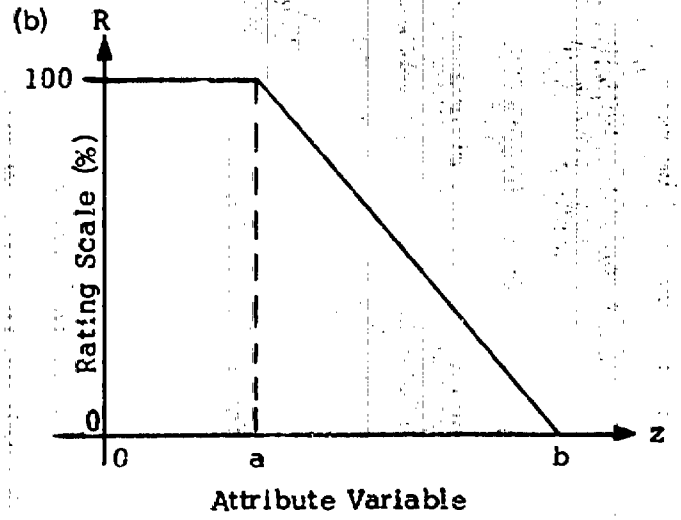
This effectiveness rating procedure for elementary factors/subfactors may also be used as a last resort when all other approaches fail for any reason. A disadvantage of this approach (as is the case with effectiveness rating functions based on ranking) is that when used in conjunction with available quantitative attribute data, the degrees of differences between candidate systems are not adequately reflected because the rating is not based on the actual value of the attribute data but rather on a predetermined value. Another disadvantage is that this rating procedure is highly subjective and may result in relatively poor repeatability.

A Generalization for ERFs

It is noted from the earlier discussions that the formulation of effectiveness rating functions (ERFs) could be difficult, time consuming and may require a great deal of ingenuity due to the variety of different types of ERFs. While the development of ERFs could not be reduced to a simple, mechanical procedure requiring no investment of creative thinking, it is possible to outline a systematic procedure which can be followed to arrive at a formulation of the desired ERFs. Furthermore, this systematic procedure is sufficiently general to accomodate all types of ERFs usually encountered, as well as the different types of effectiveness attribute data associated with the different types of ERFs. As will be seen, this generalized approach reduces the entire process of formulating ERFs to one of choosing an appropriate attribute variable as well as its lower and upper limits. All the rest follows automatically.

The format of the generalized ERF is depicted in Figure 9. The generalized ERF in (a) is used for attribute variables of a type for which a larger value is more favorable (i.e., represents a "better" candidate) than lower values, and (b) is used for attribute variables of the type that "reward"





$R = 0, \quad z \leq a$

$R = \frac{100}{(b-a)} (z-a), \quad a < z < b$

$R = 100, \quad z \geq b$

$R = 100, \quad z \leq a$

$R = 100 - \frac{100}{(b-a)} (z-a), \quad a < z < b$

$R = 0, \quad z \geq b$

Figure 9

GENERALIZED EFFECTIVENESS RATING FUNCTIONS

systems which have lower values of the attribute variable. As will be seen shortly, the linear relationships of the ERFs in (a) and (b) do not imply that the ERF chosen will result in a linear relationship between the elementary factor/subfactor rating (R) and the associated raw system/vessel attribute data. Non-linear relationships are readily established by the proper choice of an appropriate attribute variable (z).

As was indicated previously, the important issue is the formulation of the attribute variable z which in turn could be a function of one or more system/vessel characteristics or attributes. The concepts involved can best be described through a number of examples.

Consider first the case in which the attribute variable is a function of a single system/vessel characteristic x. As an example, the system/vessel characteristic or raw attribute data x could be the holding time of a WMS expressed as a percentage of the maximum holding time required for the vessel. If one did not have a strong opinion regarding the "worth" of holding times less than 100%, then one might choose to use a linear relationship between holding time and effectiveness rating, R, by relating the attribute variable z to the system characteristic x linearly, i.e.,

$$z = x$$

This yields an ERF of type (a) in Figure 9, in which a = 0, b = 100 and a functional relationship of the type

$$R = z = x, \qquad 0 \leq x \leq 100$$

If, however, one felt that a holding time close to 100% is "worth" a lot and hence candidate systems should be greatly "rewarded" for "good" holding times, then one might decide to relate the attribute variable z to the system characteristic x by

$$z = x^2$$

This yields an ERF of type (a) in Figure 9, in which a = 0, b = 10,000 and a functional relationship of the type

$$R = \frac{100}{10,000}\ z = \frac{x^2}{100}, \quad 0 \leq x \leq 100$$

If one felt even stronger about the value of "good" or "poor" holding times, then one could emphasize differences in system holding times even to a greater extent by using the relationship

$$z = x^n, \quad n = 3, 4, \ldots\ldots$$

The resulting ERF would then be (with a = 0, $b = 100^n$)

$$R = \frac{100}{100^n}\ z = \frac{x^n}{(100)^{n-1}}, \quad 0 \leq x \leq 100$$

Another way to accentuate differences is to use an exponential relationship between holding times and system ratings by choosing a relationship of the type

$$z = e^x$$

The resulting ERF would be (with a = 1, $b = e^{100}$)

$$R = \frac{100}{(e^{100}-1)}\ (z-1), \quad 1 \leq z \leq e^{100}$$

$$R = \frac{100}{(e^{100}-1)}\ (e^x-1), \quad 0 \leq x \leq 100$$

On the other hand, if one felt that changes in holding times from system to system should be deemphasized, then one could choose a relationship of the type

$$z = \sqrt{x},$$

which would result in an ERF of the type (with $a = 0$, $b = \sqrt{100} = 10$)

$$R = \frac{100}{10} z = 10\sqrt{x}, \quad 0 \leq x \leq 100$$

Further deemphasis can be obtained by using a relationship of the type

$$z = \sqrt[n]{x}, \quad n = 3, 4, \ldots\ldots,$$

which would yield an ERF of the type (with $a = 0$, $b = \sqrt[n]{100}$)

$$R = \frac{100}{\sqrt[n]{100}} z = \frac{\sqrt[n]{x}}{100^{\frac{1}{n}} - 1}, \quad 0 \leq x \leq 100$$

Even greater deemphasis can be obtained by relating z and x logarithmically as follows:

$z = \log (x + c)$, where c is an arbitrary positive constant

This would result in an ERF of the type (with $a = \log c$, $b = \log (100 + c)$)

$$R = \frac{100}{\log (100+c) - \log c} (z - \log c), \quad \log c \leq z \leq \log (100+c)$$

$$= \frac{100}{\log\left(\frac{100}{c} + 1\right)} (\log (x+c) - \log c)$$

$$R = \frac{100 \log\left(\frac{x}{c} + 1\right)}{\log\left(\frac{100}{c} + 1\right)}, \quad 0 \leq x \leq 100$$

In the above examples, x was assumed to be a continuous variable. However, the procedure outlined above for ERFs is sufficiently general to accommodate system/vessel attribute data which are represented by discrete variables.

A generalization of this procedure is provided by the situation in which the system/vessel attribute data consists of a set of numbers x_i, $i = 1, 2 \ldots n$ (e.g., the number of parts required from each category i or historical data representing equipment failure times). The attribute variable may be chosen as the average value of x, i.e,

$$z = \bar{x} = \frac{1}{n} \sum_{i=1}^{n} x_i$$

or the kth moment of x, i.e.,

$$z = \frac{1}{n} \sum_{i=1}^{n} x_i^k \quad , \quad k = 2, 3, \ldots$$

Another possibility is to apply a weight to each value of x_i (e.g., the average periodicity of maintenance activities weighted by the duration of each activity) and use an attribute variable of the type

$$z = \frac{\sum_{i=1}^{n} W_i X_i}{\sum_{i=1}^{n} W_i}$$

As a further generalization of the approach for formulating ERFs, consider the situation in which the system/vessel attribute data is characterized by two (or more) variables. An example of such a situation may be an ERF for evaluating the personnel safety of candidate system/vessel combinations with respect to a given hazard. The safety may be characterized by the following two variables:

- x_i - The likelihood of the occurrence of the hazard, which takes on any one of a specified set of n discrete numbers
- y_i - The intensity level of the hazard, which takes on any one of a specified set of k discrete numbers

The attribute variable can be chosen as a Hazard Index defined as

$$z = x_i y_i$$

It is clear that z is a discrete variable which can take on any one of n(k) values. The generalization of this procedure to more than two variables is obvious.

In the above examples, the procedure for formulating an ERF consists of proceeding as follows:

- Choose the functional form of the attribute variable z in terms of the x_i, i.e., choose the functional form of

$$z = f(x_1, x_2, \ldots x_n)$$

- Determine the ERF type which is applicable, i.e., either type (a) or (b) of Figure 9,
- Determine the lower and upper limits of z, a and b, respectively. The lower limit will yield a rating R of 0 and the upper limit will yield a rating R of 100%, or vice versa.
- Draw a straight line with slope $\frac{100}{b-a}$ for the relationship of the rating R in terms of the attribute variable z in the range a to b. This graph or analytic expression can then be used to rate any candidate system/vessel combination.

It is noted that, since only two axes are available for displaying the ERF, the functional relationship can be pictorially shown only in terms of R and the attribute variable z. In the examples where z was a function of a single variable x (continuous or discrete), it is possible pictorially to display the rating R as a function of either the attribute variable z or the system/vessel characteristic x.

A Desirable Property for Attribute Variables

Having developed a generalized and systematic procedure for formulating ERFs, it now is necessary to discuss a property of attribute variables which is very desirable and hence every effort should be made to ensure that it is accommodated when choosing an attribute variable. The purpose of this property is to facilitate a systematic development of the necessary subsystem attribute data in a convenient format which can then readily be used for evaluating candidate system/vessel combinations which are made up of either different combinations of subsystems or duplicate systems.

The desired property is the ability to establish a functional relationship for the attribute variable of any candidate system/vessel combination in terms of the attribute variable of its constituents or duplicate systems. Thus, if $z_1, z_2, \text{---} z_n$ represent the same type of attribute variable for different subsystems or duplicate systems, then the attribute variable, z, of the entire system/vessel combination is given by

$$z = f(z_1, z_2, \ldots, z_n)$$

Some examples of possible attribute variables which have this property are as follows:

$$z = z_1 + z_2 + \ldots + z_n \quad , \quad \text{where}^*$$

$$z_i = \sum_j x_j \, , \qquad \text{where}$$

x_j may represent the duration of each maintenance action, number of parts of type i required, etc., for a subsystem or for one of the multiple systems

*More generally z_i can be of the form $z_i = \sum_j f(x_j)$

$z = \text{Max}\ (z_1, z_2, \ldots z_n)$, where

z - Odor level or hazard level of a subsystem

$z = \text{Min}\ (z_1, z_2, \ldots z_n)$, where

z_i - Ability of subsystem to handle additional personnel, foreign materials, etc.

$z = \prod_{i=1}^{n} z_j$, where

$z_j = e^{x_j}$

etc.

It is noted that an attribute variable based on an average or a higher order moment, i.e.,

$$z = \bar{x} = \frac{1}{n} \sum_{i=1}^{n} x_i$$

or

$$z = \frac{1}{n} \sum_{i=1}^{n} x_i^k, \quad k = 2, 3, \ldots$$

does not possess this desirable property. The approach to be followed in situations of this type is to compute and store two (or more, as required) parameters for the attribute variable of a subsystem and "pass" these parameters into the expression for the attribute variable of the system. Thus, in the above examples, one could compute and store the two values

$$n, \text{ and } \sum_{i=1}^{n} x_i$$

or

$$n, \text{ and } \sum_{i=1}^{n} x_i^k$$

The attribute variable for the entire system composed of two subsystems can then be obtained from the above parameters as

$$z = f(z_1, z_2) = \frac{1}{n}\sum_{i=1}^{n} x_i = \frac{1}{n_1+n_2}\left(\sum_{i=1}^{n_1} x_i + \sum_{j=1}^{n_2} x_j\right)$$

$$z = f(z_1, z_2) = \frac{1}{n}\sum_{i=1}^{n} x_j^k = \frac{1}{n_1+n_2}\left(\sum_{i=1}^{n_1} x_1^k + \sum_{j=1}^{n_2} x_j^k\right)$$

The extension of this approach to attribute variables of the type

$$z = \frac{\sum_{i=1}^{n} x_i y_i}{\sum_{i=1}^{n} x_i} \quad \text{or} \quad z = \frac{\sum_{i=1}^{n} x_i y_j w_i}{\sum_{i=1}^{n} x_i w_i}$$

is obvious.

There are, however, attribute variables for which this property does not hold. Some examples of such functional relationships are

$$z = \sqrt{x}$$

$$z = x^2$$

etc.

The procedure to be followed in cases of this type is to preserve the raw system/vessel characteristic x of the subsystem or of one of the multiple systems and to "pass" this attribute data into the expression for the attribute variable for the entire candidate system configuration.

DEVELOPMENT OF EFFECTIVENESS ATTRIBUTE DATA

The type of system/vessel effectiveness attribute data required for the quantification of effectiveness is completely defined by the attribute variables associated with the ERFs for each elementary factor/subfactor.

However, it is noted that the formulation of the attribute variables has to take into account the availability (at a reasonable expenditure of time, effort and funding) of the required data as a basis for "measuring" the pertinent system/vessel characteristics. Thus, although formally one may view the development of ERFs and the development of effectiveness attribute data as independent efforts, in practice these two efforts need to be carefully coordinated in order to ensure a proper match between data required and data which can readily be made available. On the other hand, it is also important to ensure that the attribute variables chosen make full use of the data which is available (or can readily be made available) so that no data is "wasted" by not being used.

An effectiveness assessment of the viable candidate system/vessel combinations generally is broad in scope and will thefefore encompass almost all pertinent characteristics or attributes of the available candidates. As a result, effectiveness attribute data will usually cover the entire range of physical characteristics (e.g., weight, volume, maximum height), installation characteristics (flexibility of routing piping, effect on vessel stability, vessel resource requirements, etc.), performance characteristics (effect of peak loads, ability to handle foreign objects, ability to meet effluent standards, etc.), system support (i.e., operating/maintenance) characteristics (e.g., degree of automated operation, operation and maintenance personnel time/skill/training requirements, consumables and replacement part requirements), safety/habitability characteristics (e.g., presence/likelihood/intensity of various hazards to personnel, intensity of odors/heat/noise), reliability characteristics (e.g., failure frequency, amount of redundancy, equipment ratings, equipment failure independence, ability to restore failures without interrupting system operation), etc.

Effectiveness attribute data can be system dependent only (e.g., odor, noise, maximum height, effect of foreign objects) or it can be

system/vessel dependent (e.g., effect of system on vessel stability/trim and list/range/resources, ease of routing piping, the required vessel resource supplies, suitability of system for vessel, ease of installation, system configuration redundancy).

System/vessel effectiveness attribute data can be categorized into two broad classes as being either quantitative or qualitative/subjective. Quantitative attribute data can further be classified as being continuous, discrete, or quantized (i.e., continuous data which is deliberately grouped into predetermined ranges). Qualitative/subjective data can be classified as being based on subjective comparisons to an assumed standard using a set of predetermined levels or being based on absolute subjective qualitative assignments using a set of predetermined levels.

QUANTIFICATION OF EFFECTIVENESS

The previous discussions of the effectiveness model and the guidelines for developing the various elements of this model were not addressed primarily to the problem of quantifying effectiveness, although reference was made to it as being an objective of the model. Instead, the focus of attention was the development of a framework of criteria and indications of the importance of these criteria in relation to one another. However, once the effectiveness model and the associated effectiveness attribute data have been developed, the quantification of effectiveness is, in principle, a straightforward and essentially mechanical procedure (although the computations necessary are too numerous and burdensome to be performed manually).

The key elements in quantifying effectiveness are the following:

- The structure of the effectiveness model, i.e., the M/Es, the M/E factors/subfactors and their associated levels of subordination.
- The weights of the M/Es and of the factors/subfactors.

- The effectiveness rating functions.
- The effectiveness attribute data.

The basis for the quantification is the association, with each candidate, of numerical ratings (R) for the overall effectiveness (E), for each measure of effectiveness (M/E), for each factor (F), and for each subfactor (SF), including the elementary factors/subfactors (F_e/SF_e). These numerical ratings are indications of the degree to which each candidate satisfies the relevant criterion. In addition, each M/E, factor and subfactor, has a numerical weight (for relative importance) associated with it. Thus, the elements of the effectiveness model structure are characterized by either one or two numbers as follows:

$$E \longleftrightarrow R_E$$

$$M/E_i \longleftrightarrow R_i,\ W_i$$

$$F_j \longleftrightarrow R_{ij},\ W_j$$

$$SF_k \longleftrightarrow R_{ijk},\ W_k$$

$$F_e/SF_e \longleftrightarrow R_e,\ W_e$$

The procedure for performing the quantification is illustrated in Figure 10. Figure 10 summarizes the steps of the quantification procedure beginning with the effectiveness attribute data and ending with the overall effectiveness rating, showing the role of each element of the effectiveness model in this quantification. The different sources of effectiveness attribute data are also indicated.

The quantification starts with the elementary factors/subfactors, which have effectiveness rating functions associated with them. The use of effectiveness attribute data for a specific candidate system/vessel combination yield a rating for each elementary factor/subfactor. These ratings are multiplied by their associated weights and the sum of these

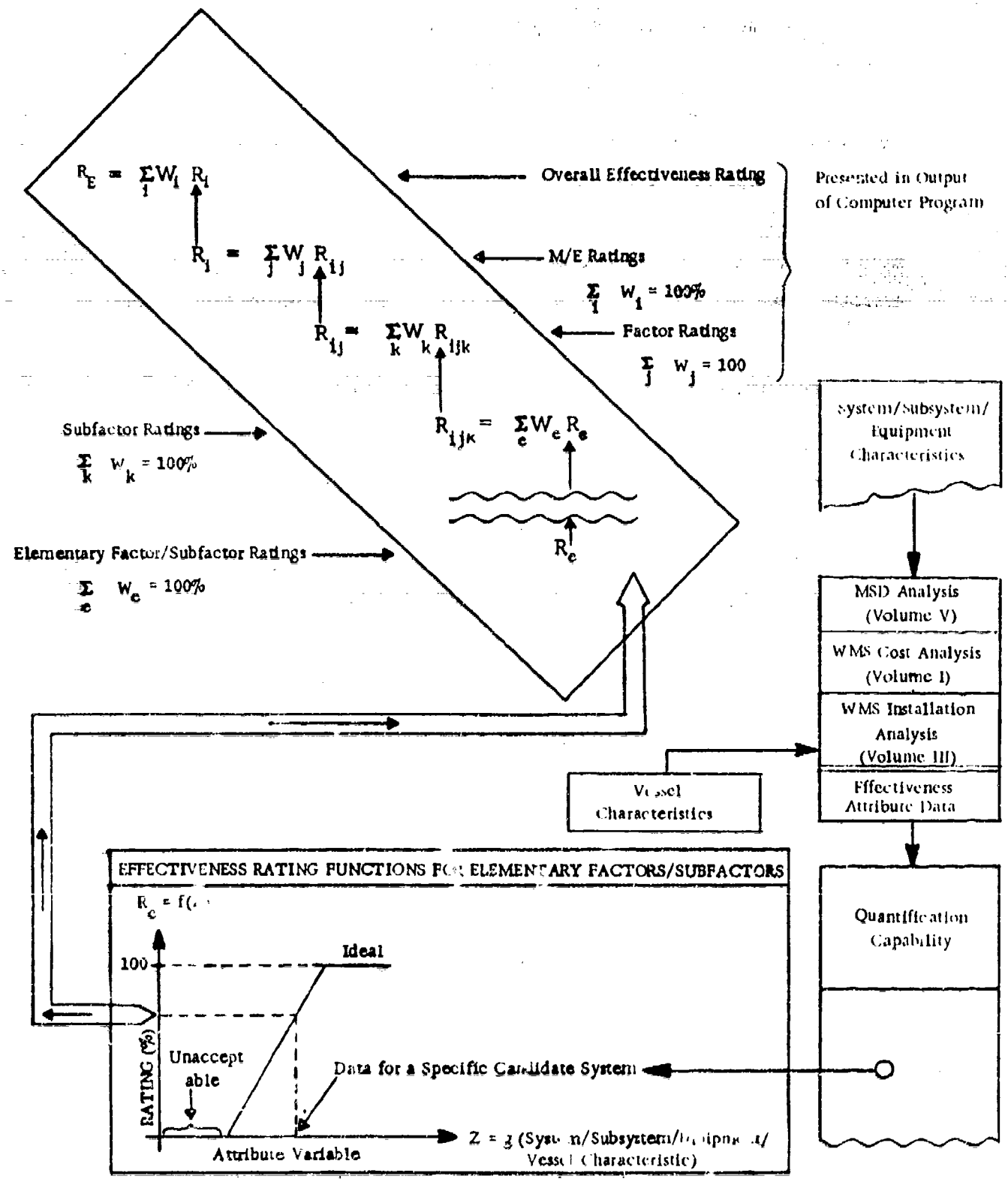


Figure 10

SUMMARY OF THE PROCEDURE FOR QUANTIFYING THE EFFECTIVENESS OF CANDIDATE SYSTEMS/VESSEL COMBINATIONS

products represents the rating for the next higher level factor/subfactor rating. Similarly, the rating for each M/E is obtained as the sum of products of the factor ratings and the associated factor weights. Finally, the overall effectiveness rating for any candidate system/vessel combination is obtained as the sum of products of the M/E ratings and the associated M/E weights. The numerical manipulations are performed by a computer program which accepts as an input the structure of the effectiveness model, the weights and the elementary factor/subfactor ratings.

SUBJECTIVE JUDGEMENT, REPEATABILITY AND VALIDITY OF RESULTS

It is noted from the foregoing discussions that subjective judgements* of the analyst play a prominent role in the development of ERFs as well as the effectiveness model structure and the associated weights. Thus, such subjective judgements become an integral part of the resulting ERFs and are therefore reflected in the effectiveness ratings of candidate system/vessel combinations for the elementary factors/subfactors (and subsequently the M/E ratings and the overall effectiveness ratings).

This raises a potentially serious question regarding the meaning and validity of the results. Thus, if the effectiveness ratings are dependent on the particular analyst conducting the study, then it might be inferred that if different decision makers conducted the analysis, different results might be obtained, i.e., the results are not necessarily repeatable across different analysts. Such an a priori conclusion regarding the seeming lack of "stability" of the results, may be alarming or disturbing and may prompt questions as to the identity and source of the "real" or "true" ERFs. It is noted that a similar issue can be raised regarding the structure of the effectiveness model and the associated weights.

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* It is noted that "subjective judgement" is somewhat of a redundancy since it is questionable whether there is such a thing as "objective judgement". Thus, if the judgement were purely objective, it would imply that the same conclusion could be arrived at by logical deduction, in which case, it would not be a judgement but rather a determination and, in fact, could be performed without human intervention - e.g., by a computer.

The resolution of this apparent dilemma lies in the nature, definition, and intent of an effectiveness analysis. It will be recalled that effectiveness was defined as inherently being subjective in nature and dependent on the decision-maker, i.e., effectiveness is what the decision-maker says it is, or, effectiveness is in the eyes of the beholder. Although this may seem like a circuitous and self-serving definition of effectiveness, it is noted that it corresponds to the manner in which decisions are made by individuals whether in their personal lives or in making consequential decisions based on highly technical information. In fact, making a decision, by definition, implies the exercise of a subjective and judgemental faculty, rather than a process of arriving at a conclusion on the basis of some objective set of rules. Thus, for example, it would not be meaningful to ask someone to decide whether system A weighs more than system B. Rather, one can be asked to determine whether system A weighs more than system B. On the other hand, one cannot determine, but rather one would have to decide, whether one system aspect is more important, better, nicer, worthier, preferred, etc., than another.

Another point to keep in mind in connection with the nature of the above dilemma is that a numerical quantity for effectiveness is not meaningful in an absolute sense but only in a relative sense. Thus, regardless of the specific numerical assignments that are made, as long as they are consistent, differences among candidate system/vessel combinations can be brought out. This is the basic purpose of an effectiveness analysis. An effectiveness analysis is not in itself a decision-making process. Instead, effectiveness analysis is a tool which the decision-maker can use to obtain the information he needs in a systematic manner and organize it in a convenient form for use by him in the decision-making process.

SOME CHARACTERISTICS AND FEATURES OF THE EFFECTIVENESS ASSESSMENT METHODOLOGY

The effectiveness assessment methodology developed as part of this study has been found to be applicable for quantifying the effectiveness of candidate system/vessel combinations at several levels of detail. It thus enables a decision-maker to compare candidates with respect to different individual aspects of effectiveness as well as the overall effectiveness. If used properly, this methodology can serve as a useful analytic tool for cost-effectiveness studies, trade-off studies, sensitivity analyses, etc. Some of the relevant characteristics and features of this methodology are as follows:

- It can accommodate all considerations of interest to the decision-maker.
- It synthetizes technical and objectively determined quantitative system/vessel data with qualitative system/vessel information and subjective judgements of the decision-maker.
- It is highly flexible with respect to the range and magnitude of the problems it can accommodate. Thus, the analysis can be either very detailed and comprehensive which may be suitable for large-scale systems, or it can be much smaller in scope and less detailed as warranted by the objectives of the study and the data available.
- It provides results at several levels of detail. Effectiveness ratings for each candidate are provided on three levels as follows:
  - An overall effectiveness rating
  - A rating for each effectiveness measure
  - A rating for each elementary factor/subfactor
- It provides a means of determining the effect of changes in data, assumptions, subjective judgements, etc.

- It has been found that application of the methodology tends to clarify issues, may result in a fresh outlook and often new insights are gained, even by knowledgeable individuals who are familiar with the problem. This is due to the following aspects of the methodology:

  - Effectiveness is defined in terms of, and directly related to, the objectives, requirements and constraints of the problem.

  - Development of the structure of the effectiveness model requires the determination of overall assessment criteria followed by a systematic and successive breakdown of each overall criterion into constituent sub-criteria. This process results in an in-depth examination of the problem. Thus, issues which have either been overlooked or which were vague and ill-defined are identified and resolved.

  - The need to assign a weight to designate the relative importance of each criterion encourages reflection on the basic issues pertaining to the objectives, requirements, etc.

  - Development of effectiveness rating functions results in consideration of the relevant requirements, constraints, the type of data available, the level of detail of the analysis, and identification of the judgements used in deciding what is desirable as well as undesirable.

PROPERTIES, INTERPRETATION AND USE OF EFFECTIVENESS RATINGS

Meaning of Effectiveness Ratings

Although the overall effectiveness rating of a candidate is a number in the range of 0 to 100%, it cannot be legitimately interpreted as a probability. Instead, the rating should be interpreted as a measure of the overall

quality or "worth" of the candidate, determined as a weighted average of all considerations, i.e., the extent to which the aggregate of all the individual criteria are satisfied, weighted by the importance of each one relative to the others. Also, overall effectiveness ratings are to be used mainly for comparing candidate systems rather than in an absolute sense.

Similarly, the ratings of candidates with respect to individual M/Es are not to be interpreted as probabilities. It is especially important to keep this in mind when considering M/Es whose attributes or characteristics are usually given as probabilities.

Examples of such M/Es are "RELIABILITY" and "MAINTAINABILITY" whose ratings for a given candidate system do not have the usually used interpretation of being the probability that the system will not fail for a given period of time (Reliability) or the probability that the system will be restored within a given time interval (Maintainability). Instead, the ratings of candidates with respect to these M/Es are to be used for comparing the Reliability and Maintainability of the candidate systems. Furthermore, these M/E ratings may be based either entirely on objectively determined quantitative data, or partially on such data and partially on qualitative system information and subjective judgements. Hence, it is important to be aware of the distinction between the Reliability and Maintainability of a candidate system, which are characteristics or attributes of the system, and the effectiveness ratings of the system for the M/Es "RELIABILITY" and "MAINTAINABILITY" which include subjective judgements pertaining to such issues as what constitutes minimum acceptable and ideal levels as well as the "worth" of intermediate levels of the values for these attributes. It is noted that the Reliability or Maintainability of a candidate system, i.e., the associated probability values, may serve as an input (i.e., the attribute variable in the effectiveness rating function) in rating the system for the M/Es "RELIABILITY" and "MAINTAINABILITY", but the rating may be based on other inputs as well. If these probabilities are used as the attribute variable and a linear relationship is used as the basis for the effectiveness

rating function (ERF), then the ratings for these M/Es take on the values of the system Reliability and Maintainability characteristics.

The Effect of Weights and Levels of Subordination

Variations in overall effectiveness rating (R_E) across candidate systems are generally of smaller magnitude than variations in ratings with respect to any one M/E for different systems. Also, a variation in the value for overall effectiveness rating of a system is much more significant than a variation of the same magnitude in the system rating (R_i) with respect to any one M/E alone. The reason for these two conclusions is that the overall system effectiveness rating is obtained as a sum of the weighted system ratings with respect to the M/Es. Since the weights are all in the range of 0 to 100% (and their sum is 100%), they tend to smooth out (and sometimes swamp) the variations in M/E ratings. Thus, a very large variation in any one M/E rating must occur in order to have any significant effect on the overall effectiveness rating (if everything else is held constant). And, in order to produce a large upward (downward) variation in the overall effectiveness rating, extremely large upward (downward) variations in the ratings with respect to several M/Es must occur simultaneously (if no other variations occur).

The above conclusions can be simply illustrated with some numerical examples. Thus, a 10% change in a system rating with respect to an M/E which has a weight of 10% will result in only a 1% change in the overall effectiveness rating for that system. Similarly, even for an M/E which has a weight of 25%, a 10% change in the system rating with respect to this M/E will result in only a 2.5% change in the overall effectiveness rating for this system.

Since each M/E which is represented in the effectiveness model is generally weighted in such a way that it alone does not dominate the overall effectiveness rating, it is necessary to exercise some caution in using the overall effectiveness rating values for making decisions. This indicates

the importance of examining the individual M/E ratings of a candidate in addition to its overall effectiveness rating.

Similar conclusions can be drawn with respect to the effect of factor weights on the corresponding M/E rating and the effect of subfactor weights on the corresponding factor ratings. In addition, this effect is multiplicative when more than one level is considered. It is noted that this is not an unexpected result and it is consistent with the fact that, generally, as the number of considerations determining the outcome of a decision is increased, the influence of any one consideration on the decision must, of necessity, decrease. Thus, the overall effectiveness rating is less sensitive to variations in factor ratings than it is to similar variations in M/E ratings, etc. On the other hand, it should be kept in mind that the overall effectiveness of a system is defined in terms of the aggregate of all criteria rather than in terms of any one criterion, and the weight assignments for relative importance imply the manner in which the decision-maker is willing to trade-off one criterion (consideration) for another one.

Use of Effectiveness Ratings

Effectiveness ratings reflect the characteristics and features of the effectiveness assessment methodology discussed earlier and hence the resulting effectiveness ratings should be interpreted accordingly. Following are some guidelines for the use and interpretation of the overall effectiveness ratings as well as the ratings for each M/E.

> The effectiveness assessment methodology does not in itself constitute an automated decision process which eliminates the need for a decision-maker. Instead, the effectiveness assessment methodology is a tool to be used by the decision-maker as an aid in analyzing and evaluating the candidates. As a result, the effectiveness ratings should not be thought of as automatic indicators of the effectiveness of the candidates independently of the decision-maker so that the necessity for any further considerations is eliminated. Instead, since effectiveness ratings represent the

quantitative result of the synthesis of objective and subjective system information, assumptions, requirements and the subjective judgements of the decision-maker, they should be used as a basis for making comparisons, trade-offs, analysing the effects of changes in data and/or assumptions, etc.

- Effectiveness ratings should not be used as the basis for determining the viability of potential candidates. Such a determination must be made prior to the effectiveness analysis as part of a preliminary analysis on the basis of gross considerations, (i.e., minimum requirements) to eliminate non-viable candidates. As indicated in the discussion on the effect of weights on ratings, the effectiveness ratings are not adequate for providing the type of gross differences between candidates which are required for a preliminary analysis.

- The effectiveness ratings are most meaningful when used and interpreted in the context of the effectiveness model. Hence, the more familiar one is with the effectiveness model, the more meaningful are the ratings.

- Although the overall effectiveness ratings of a candidate are the most important and most often used indicator (figure of merit) of the effectiveness assessment, the individual M/E ratings for the candidate should also be examined and the reasons for either poor or high ratings should be understood. These M/E ratings may sometimes provide a rationale for a decision which overrides the importance of either a low or a high overall effectiveness rating.

- The overall effectiveness rating of a candidate is a quantitative indication of its overall quality and hence is a convenient figure of merit which can be used as a basis for comparing and or ranking the candidates being considered.

Although the effectiveness ratings are most meaningful in a relative sense when comparing candidates against one another, rather than in an absolute sense, the rating for a candidate may be used as a rough indication of how well or how poorly the candidate is likely to fulfill the established goals and requirements. Thus, an overall effectiveness rating of 100% means complete satisfaction of all stated goals and requirements. Hence, if the overall effectiveness ratings for all candidates are low, and especially if the variation among them is small, it may be the basis for a decision that none of the available candidates are acceptable since the objectives and requirements are not likely to be met by either one of them. Prior to forming such a conclusion, one should first re-examine the effectiveness model used to ascertain that it is a reasonable conclusion. The extent to which effectiveness ratings can be used in an absolute sense rather than in a relative sense depends largely on the nature of the elementary factor/subfactor effectiveness rating functions (ERFs) used. Specifically, the important consideration in this regard is whether the rating is based on comparison of the attribute data to an absolute value or it is based on comparing all other candidates to the candidate having the largest (or smallest) value of the attribute variable, i.e., a rating based on scaling. ERFs based on comparison with an absolute value yield an effectiveness model which lends itself more readily for using effectiveness ratings as a basis of direct comparison of candidates with objectives and requirements, than do ERFs which are based on scaling procedures. On the other hand, it is usually more difficult to formulate ERFs based on comparison with an absolute value, since it generally is not obvious or easy to find a basis for establishing the level of such an absolute value.

The interpretation of effectiveness ratings should be guided by the following considerations:

- An elementary factor/subfactor rating of zero for any candidate does not imply that the candidate, as a whole, is unacceptable. Instead, this should be interpreted as meaning that a particular aspect of the candidate (among many others being considered) which is represented by the given ERF is not acceptable. This point is best illustrated by an ERF which has two discrete values only, namely, 0 and 100, and which usually arises from a yes or no question.

- Overall effectiveness ratings as well as individual M/E ratings should be interpreted in the context of a weighted average of multiple considerations. Hence, as was pointed out in the discussion on the effect of weights and levels of subodination on ratings, no one consideration can generally dominate these ratings.

- Since the overall effectiveness rating (or even individual M/E ratings) will generally not be sufficiently sensitive to variations in ratings for individual considerations (i.e., criteria) which are of special interest to a decision-maker, it is necessary to make special provisions for drawing attention to such individual considerations. An effective way of accomplishing this is the technique of "flagging" the criteria of interest by listing the effectiveness ratings for them in a prominent position when presenting the results of the analysis. In the candidate system/vessel combinations analyzed as part of this study, the holding capacity of each system for black and gray wastewater was thus flagged by listing the ratings for these two criteria in tables showing the results of the analysis.

COMPUTER PROGRAM FOR QUANTIFYING THE EFFECTIVENESS OF CANDIDATE SYSTEM VESSEL COMBINATIONS

This section of the report documents the computer program for quantifying effectiveness. It consists of the following:

- A summary of the program features, limitations, and input requirements.
- Instructions for preparing the input.
- A sample problem. The sample problem consists of the viable candidate system vessel combinations included in this study. Since these candidate system/vessel combinations are discussed in detail in this volume as well as in the other volumes of this report, no further discussion of the problem appears in this section except a listing of the actual input to the computer program.
- A description of the program including overall and detailed program flowcharts.
- Program listings (card images).

SUMMARY OF PROGRAM CHARACTERISTICS

Output Format

A sample output of the computer program for quantifying the effectiveness of candidate systems/vessel combinations is presented in below. Some of the important features and contents of the output are as follows:

- A separate page is presented for each vessel and all candidate systems are listed on this page.
- Vessel identification by user specified designation
- Candidate system identification by user specified designation
- Effectiveness ratings (given as a % in the range of 0 to 100 rounded to the nearest percentage point) for each candidate system on the given vessel as follows:
  - Overall effectiveness
  - Rating with respect to each measure of effectiveness (M/E) which is identified by user specified designation.
- The weight for each M/E (given in parenthesis under each M/E as a % in the range of 0 to 100 rounded to the nearest percentage point).
- Identification of non-viable system/vessel combinations (designated by N/A in the output).

Program Features

Some of the important features of this computer program are as follows:

- The output is presented on a per vessel basis. For each vessel the output presents information on each candidate system (ratings for each M/E, M/E weight, overall effectiveness rating, non-viable system/vessel combinations).

VESSEL GALLATIN (378') WHEC-721

* * * * * MEASURE OF EFFECTIVENESS (AND ASSOCIATED WEIGHT) * * * * *

SYSTEM NO. NAME	ADAPT FOR SHIP INST (8)	PERFORM-ANCE (15)	OPERA-BILITY (12)	PERSONNEL SAFETY (11)	HABITA-BILITY (17)	RELIA-BILITY (23)	MAINTAINA-BILITY (14)	OVERALL EFFECTIVENESS (E)
1 GRV COL/B(HLT)/G(HLT)	88	72	91	95	75	96	92	87
2 RECIRC/B(CHLR+HLT)/G(HLT)	81	67	55	88	51	91	81	74
3 RECIRC/B(CHLR+INC)/G(HLT)	78	76	58	82	36	84	81	70
4 GRV COL/B(GRM+HLT)/G(HLT)	77	70	79	94	58	85	79	77
5 GRV COL//B+G(GRM+HLT)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6 GRV COL/B(HLT)/G(GRM+HLT)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7 GRV COL/B(GRM+INC)/G(HLT)	73	72	70	80	43	83	80	71
8 GRV COL//B+G(GRM+INC)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9 VAC COL/B(HLT)/(HLT)	72	69	65	95	71	44	53	64
10 VAC COL/B(INC)/G(HLT)	69	70	53	92	64	33	53	57
11 VAC COL/B(EVAP)/G(HLT)	65	58	64	91	65	42	41	58
12 VAC COL/B(HLT)/G(GRM+HLT)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
13 VAC COL/G(GRM)/B+GS(INC)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
14 PMP COL/B(HLT)/G(HLT)	71	70	86	93	67	76	49	72
15 PMP COL/B(INC)/G(HLT)	67	68	74	91	50	64	49	65
16 PMP COL/B(EVAP)/G(HLT)	64	53	85	89	60	74	41	67
17 PMP COL/B(HLT)/G(GRM+HLT)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
18 PMP COL/G(GRM)+GS(INC)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

- The number of vessels and the number of candidate systems are variable input parameters for the program.
- Vessels, candidate systems, and M/Es are identified in the output by user specified designations.
- Masking capability for designating non-viable system/vessel combinations.
- M/E weights must be vessel and system independent
- Factor/subfactor weights must be system independent but may be vessel dependent. If any factor/subfactor weight is vessel indepdent, this fact can be conveyed to the program and only one weight need be specified.
- Effectiveness ratings of elementary factors/subfactors are system dependent and may also be vessel dependent. If these ratings are vessel dependent this fact can be conveyed to the program and a separate set of candidate system ratings must be given for each vessel.
- Unique identification of all input cards. In particular, every factor/subfactor weight and rating card is uniquely identified, not only with respect to level of subordination but also with respect to the M/E it belongs to and its sequence within the M/E (which conveys effectiveness model structure information to the program). Thus, if input cards are accidentally misplaced within the input deck, the computer program will rearrange them (internally) in the correct sequence.
- Error checking capability as follows:
  - A check that input data is provided for all vessels (i.e., factor/subfactor weights) and all candidate systems (i.e., elementary factor/subfactor ratings).

- A check that all M/E weights, all factor/subfactor weights, and all elementary factor/subfactor ratings are legitimate numbers, i.e., numbers in the range of 0 to 100% rounded to the nearest percentage point.
- A check that the sum of all M/E weights is 100% and a check that the sum of the factor/subfactor weights at every level of subordination is 100% in every M/E.
- A check that candidate system/vessel ratings are provided for every elementary factor/subfactor and that no superfluous ratings are provided.

If an error is detected in the input data, the program will produce an error message, indicating which vessel, system, or M/E the error is associated with. Also, if appropriate, the punched card associated with the error will be reproduced.

Program Limitations

The program limitations with respect to the maximum values for the various input parameters are as follows:

- Number of vessels - 20
- Number of candidate systems - 30
- Number of M/Es - 15
- Number of levels of subordination within each M/E - 5
- Number of factors/subfactors of the same level at any given level of subordination - 9

Input Requirements

The inputs to the computer program required in order to quantify the effectiveness of candidate system/vessel combinations are as follows:

- The number of vessels (limited to 20) and the number of candidate systems (limited to 30) given on N cards.
- Vessel identification (assigned number and name designation) given on V cards.
- Candidate system identification (assigned number and name designation) given on S cards.
- Identification of non-viable system/vessel combinations given on K cards.
- M/E identification (limited to 15), including the following information and constraints (given on M cards):
  - Assigned M/E number
  - M/E name designation
  - M/E weights, subject to the following limitations:
    - M/E weights are system and vessel independent
    - M/E weights are given as a % in the range of 0 to 100, rounded to the nearest percentage point.
    - The sum of all M/E weights must be equal to 100%, i.e.,

$$\sum_{\text{All M/Es}} W_j = 100$$

- Effectiveness model structure identification and weights for every factor/subfactor within each M/E (given on W cards), including the following information and constraints:
  - The assigned number of the M/E
  - The current and all prior levels of subordination (limited to 5 indentures) within the M/E and the sequence number (limited to 9) at the current level of subordination of each factor/subfactor. This information is given as a single

number from 1 to 5 digits (each digit ranging from 1 to 9) and uniquely identifies each factor/subfactor as well as the structure of the effectiveness model with respect to the hierarchy of the factor/subfactor levels of subordination.

.. The weights for each factor/subfactor within each M/E, subject to the following limitations:

- Factor/subfactor weights must be system independent but may be vessel dependent.
- If the weight for any given factor/subfactor is vessel independent this fact can be conveyed to the computer program and only one weight is specified.
- If the weights for any given factor/subfactor are vessel dependent, they must be specified in the sequence corresponding to the vessel number assignments.
- Factor/subfactor weights are given as a % in the range of 0 to 100, rounded to the nearest percentage point.
- At any given level of subordination, the sum of all factor/subfactor weights at that level (and for each vessel if the weights are vessel dependent) must be equal to 100%, i.e.,

$$\sum_{\text{All factors/subfactors at the same level}} W_i = 100 \qquad \text{At any level of subordination and for each vessel}$$

Effectiveness ratings for every elementary factor/subfactor within each M/E (given on R cards), including the following information and constraints:

.. The assigned number of the M/E

.. The number which uniquely identifies every elementary factor/subfactor within each M/E (must match the corresponding number on the W cards).

.. Effectiveness ratings for each elementary factor/subfactor, subject to the following limitations:

- Elementary factor/subfactor effectiveness ratings are system dependent and may also be vessel dependent.
- If the ratings for any elementary factor/subfactor are vessel dependent, this fact must be conveyed to the computer program by identifying the corresponding vessel number of each set of candidate system ratings (specified for each vessel separately).
- Elementary factor/subfactor effectiveness ratings for each candidate system are given in the sequence corresponding to system number assignments.
- Elementary factor/subfactor effectiveness ratings are given as a % in the range of 0 to 100, rounded to the nearest percentage point.

INPUT PREPARATION

The program requires seven types of input cards. They are:

- N - Defines the number of systems and vessels applicable to the problem.
- S - Contains the number and name of each system.
- V - Contains the number and name of each vessel.
- K - Contains the systems to be masked for each vessel.
- M - Contains the measure number, weight and name.
- W - Contains the weights applicable for each factor or subfactor for each measure.
- R - Contains the ratings applicable for each elementary factor or subfactor for each measure.

The following paragraphs specify the preparation procedures to be observed for each input card type. A pictorial layout of all the card types, a coding sheet for type R cards, and a suggested sequence for the input are included at the end of the discussion.

N Cards

The N card contains the number of vessels and the number of systems involved in the problem. Only one card is to be prepared. This card type is required. The following table provides the rules for its preparation.

Col. No.	Field Name	Enter the Following Data
1-2		No entry required
3	Card Code	The letter N
4-8		No entry required
9-10	Number of Vessels	Enter the number of vessels (limited to 20) applicable to the problem. Right justify and zero fill.
11		No entry required.
12-13	No. of Systems	Enter the number of systems (limited to 30) applicable to the problem. Right justify and zero fill.
14-80		No entry required.

S Cards

One S card is to be prepared for each system applicable to the problem. Each system is to be assigned a unique number in the range of 01 to 30. These numbers should be assigned in the sequence the user wishes the systems to appear on the output report. System 01 will appear as row 1 and system 30 will appear as row 30. The following table provides the rules for the preparation of the S cards:

Col. No.	Field Name	Enter the Following Data
1-2	System Number	A unique two-character numeric in the range 01 to 30. Right justify and zero fill.
3	Card Code	The letter S.
4-6		No entry required.
7-34	System Number and Name	The two-character system number, a space, and the system name (25 characters) which will appear on the output report.
35		No entry required.
36-80	Full System Name	Any further description of the system required for identification purposes only. This entry is optional.

V Cards

One V card is required for each vessel applicable to the problem. Each vessel is assigned a unique number in the range of 01 to 20. These numbers are to be assigned in the sequence the user wishes the vessels to appear in the output report. Vessel 01 will appear on page 1 and vessel 20 will appear on page 20. The following table provides the rules for their preparation.

Col. No.	Field Name	Enter the Following Data
1-2	Vessel Number	A unique two-character numeric in the range 01 to 20. Right justify and zero fill.
3	Card Code	The letter V
4-80	Vessel Name	The vessel name which will appear on the output report. A maximum of 77 alpha numeric characters are allowed.

K Cards

The K card is to be used only if systems are not applicable for a specific vessel. One K card is required for each vessel where this condition exists. A maximum of 26 systems per vessel are allowed to be masked. The following table provides the rules for the preparation of this card type.

Col. No.	Field Name	Enter the Following Data
1-2	Vessel Number	The two-character number of the vessel within the range of 01 to 20. Right justify and zero fill.
3	Card Code	The letter K
4-5	System Number 1 (to be masked)	The two-digit system number to be masked. Right justify and zero fill if necessary.
6		No entry required.
7-80	System Number 2 through 26 (to be masked)	Continue entering the two-digit system numbers to be masked leaving a space between each. Systems must be entered in ascending numeric order.

M Cards

One M card is required for each measure applicable to the problem program. Each measure is assigned a unique number in the range 01 to 15. These numbers should be assigned in the sequence the user wishes the measures to appear on the output report. Measure 01 will appear in the leftmost column and measure 15 will be the rightmost column. The following table provides the rules for the preparation of the M cards.

Col. No.	Field Name	Enter the Following Data
1-2	Measure Number	A unique two-character numeric in the range 01 to 15. Right justify and zero fill.
3	Card Code	The letter M
4-6	Weight	The weight of the measure. Must be numeric. Right justify and zero fill.
7-16	Measure Name	The measure name that will appear on the output report.
17-26	Measure Name (continued)	This may be continued in columns 17-26. Col. 7-16 will appear as the first line and col. 17-26 will appear as the second line of the heading.
27		No entry required.
28-80	Full Measure Name	Any further description of the measure required for identification purposes only. This entry is optional.

W Cards

One W card is prepared for each factor and subfactor within each measure. A maximum of 10 weights may be entered on a card. If there are more than 10 vessels in the problem, and therefore more than 10 weights, a continuation card is to be used. The maximum number of vessels (weights) allowed is 20.

Each factor/subfactor is assigned a unique (within a measure) Factor Code Number. Both the weights and ratings are assigned the same factor code number in each measure. The following conventions are used in assigning the numbers:

- Factors are identified by a single digit number from 1 to 9.
- Subfactors are identified by a multiple digit number, the first of which is the factor digit.

A special feature of the type 'W' card is the Duplicate Code. The use of this code will simplify the preparation of these cards by the user. This code is used only when all the weights for a factor or subfactor are identical (for all vessels). When used, the letter X is entered in column 40 and the weight is entered in columns 41-43. No additional weights are to be entered when the duplicate code is entered in column 40. Additionally, if more than 10 vessels are involved in the problem and continuation cards are being used, the continuation cards are not required when the duplicate code is used.

The use of the continuation card, mentioned above, is accomplished in the following manner. The weights of the first 10 vessels are entered on the input form and a 1 is entered in column 80. The weights of the remaining vessels are entered on the next line of the input form and a 2 is entered in column 80. The information contained in columns 1 through 37 is identical on both lines of input.

The following table provides the rules for the preparation of the W card.

Col. No.	Field Name	Enter the following data
1-2	Measure Number	The measure number previously assigned on the M card. Right justify and zero fill.
3	Card Code	The letter W.
4-8	Factor Code Number	The number assigned using the rules described above. Left justify. It is not necessary to zero fill.
9-37	Description	The name of the factor/subfactor. This is for identification purposes only.
38-39		No entry required.
40	Duplicate Code	An X if all the weights are identical.
41-43	Weight (Vessel 1)	The weight for vessel 1. Must be numeric. Right justify and zero fill. If an X has been entered in column 40 no additional entries are needed.
44		No entry required.
45-79	Weights (Vessels 2-10)	The weights for each successive vessel. Must be numeric, right justified and zero filled. Each 3 position weight is separated from the next weight by a blank space.
80	Continuation Code	Only to be used if more than 10 vessels are involved in the problem. Enter a 1 on the first card and a 2 on the second. Submit only 1 card and do not make an entry in col. 80 if an 'x' has been entered in col. 40.

R Cards

This input data is prepared in a similar manner to the type W cards previously discussed. One important difference is that Type R cards are prepared for elementary factors/subfactors only. There is no input preparation for non-elementary factors/subfactors.

The ratings applicable to a problem run are normally system dependent. A maximum of 10 ratings can be entered on a single card. The maximum number of systems allowed by the program are 30, therefore allowing the user to prepare up to 3 cards per factor/subfactor. A continuation code is used to handle more than 10 systems. The ratings applicable to the first 10 systems are entered on the first card and a 1 is entered in column 80. The ratings of the 11th through 20th systems are entered on the second card and a 2 is entered in column 80. The ratings of the remaining systems are entered on the third card and a 3 is entered in column 80.

It is possible that in a particular problem some of the ratings will be both system and vessel dependent. The program allows for this possibility. For this situation, the user must enter the applicable vessel number in columns 38-39. The ratings are entered in the normal manner and continuation cards may be used if necessary.

The table on the following page provides the rules for the preparation of the type R card.

CODING SHEET FOR TYPE R CARD

SYSTEM/VESSEL RATINGS FOR ELEMENTARY FACTORS/SUBFACTORS

	M #	R	Code #	Factor/Subfactor Name	V #	System Ratings 1	2	3	4	5	6	7	8	9	10	Con't
1		R														
2		R														
3		R														
4		R														
5		R														
6		R														
7		R														
8		R														
9		R														
10		R														
11		R														
12		R														
13		R														
14		R														
15		R														
16		R														
17		R														
18		R														
19		R														
20		R														

PAGE ___ OF ___

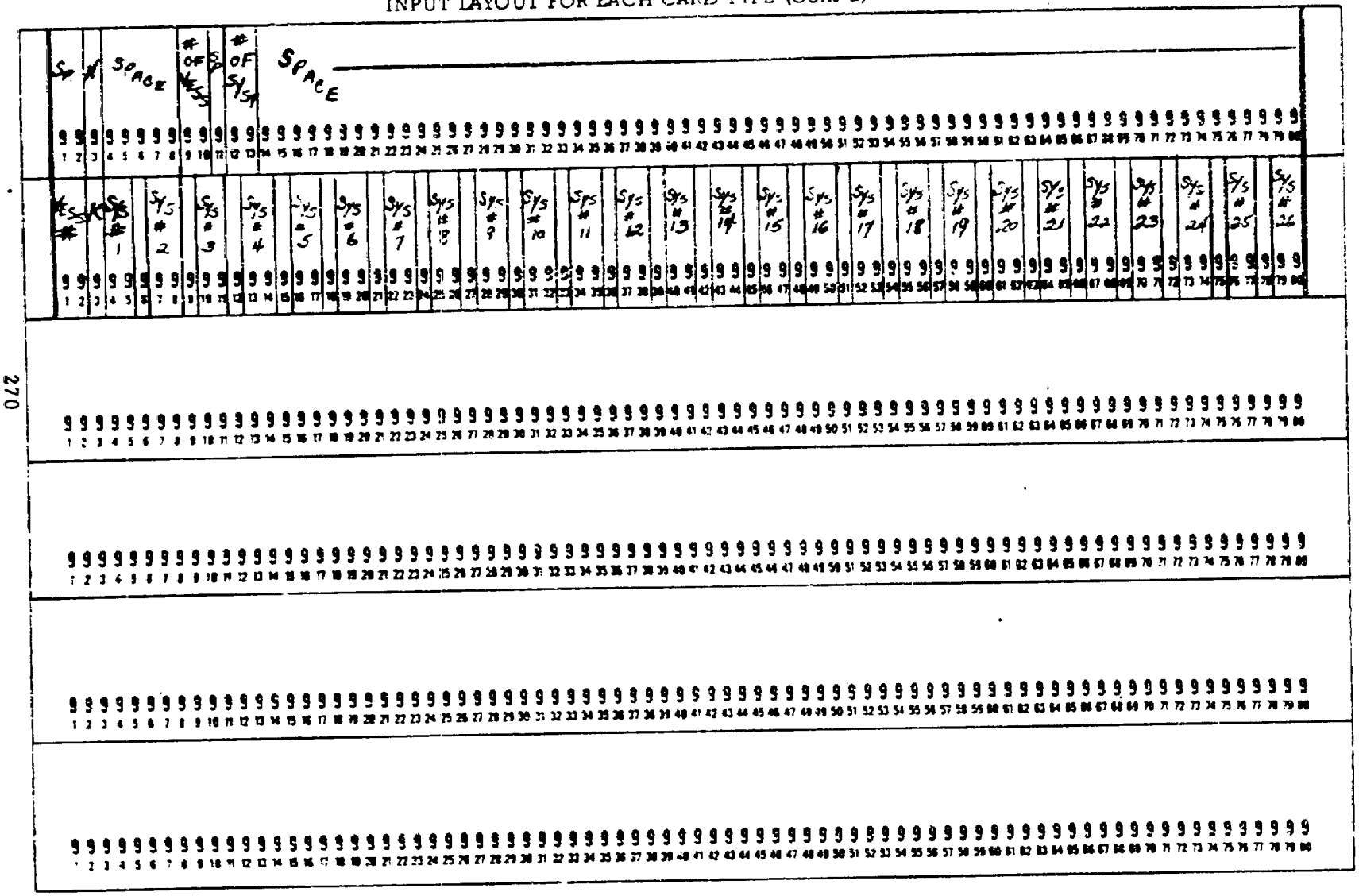
Col. No.	Field Name	Enter the Following Data
1-2	Measure Number	The measure number previously assigned on the M card. Right justify and zero fill.
3	Card Code	The letter R.
4-8	Factor Code Number	The number assigned using the rules described above. Left justify. It is not necessary to zero fill.
9-37	Description	The name of the factor/subfactor. This should match the description entered on the corresponding W card.
38-39	Vessel Number	Use only when ratings are vessel dependent. Enter the appropriate vessel number as previously assigned on the V cards.
40		No entry required.
41-43	Rating (System 1)	The rating for system 01 as designated on the S cards. Must be numeric. Right justify and zero fill. A rating must be entered for each system.*
44		No entry required.
45-79	Ratings (Systems 2-10)	The ratings for each successive system. Must be numeric, right justified, and zero filled. Each 3-position rating is separated from each other by a blank space.
80	Continuation Code	Use only when more than 10 systems are used in the problem. Enter a 1 on the first card, a 2 on the second, and a 3 on the third if there are more than 20 systems. Do not make an entry in this field if there are 10 systems or less.

* Ratings must be given even for systems which do not apply to the given vessel, i.e., non viable system/vessel combinations which are specified on the K cards. Since these ratings are eventually masked, any legitimate rating number may be used (i.e., any number between 0 and 100). A rating of 0 is suggested for convenience.

INPUT LAYOUT FOR EACH CARD TYPE

MEAS #	M	LIST OF MEAS	SHORT NAME (MEASURE) LINE 1	SHORT NAME (MEASURE) LINE 2	SP	FULL MEASURE NAME (OPTIONAL)
9 9	9	9 9 9	9 9 9 9 9 9 9 9 9 9	9 9 9 9 9 9 9 9 9 9	9	9 9 9 9 9 9 9 9 9 9

INPUT LAYOUT FOR EACH CARD TYPE (Cont'd)



Input Sequence

The following recommended sequence (shown on the following page) will provide the user ease in locating any invalid cards rejected by the edit module (step 2). The user, may, however, select any alternate sequence he may find more practical.

Card Type N - Function - sets the number of systems and vessels applicable for the particular run.

Card Type S - Function - contains the abbreviated system name (25 characters) which will appear on the output report.

Card Type V - Function - contains the vessel name which will appear on the output report.

Card Type K - Function - masking non-viable candidate systems on a vessel basis.

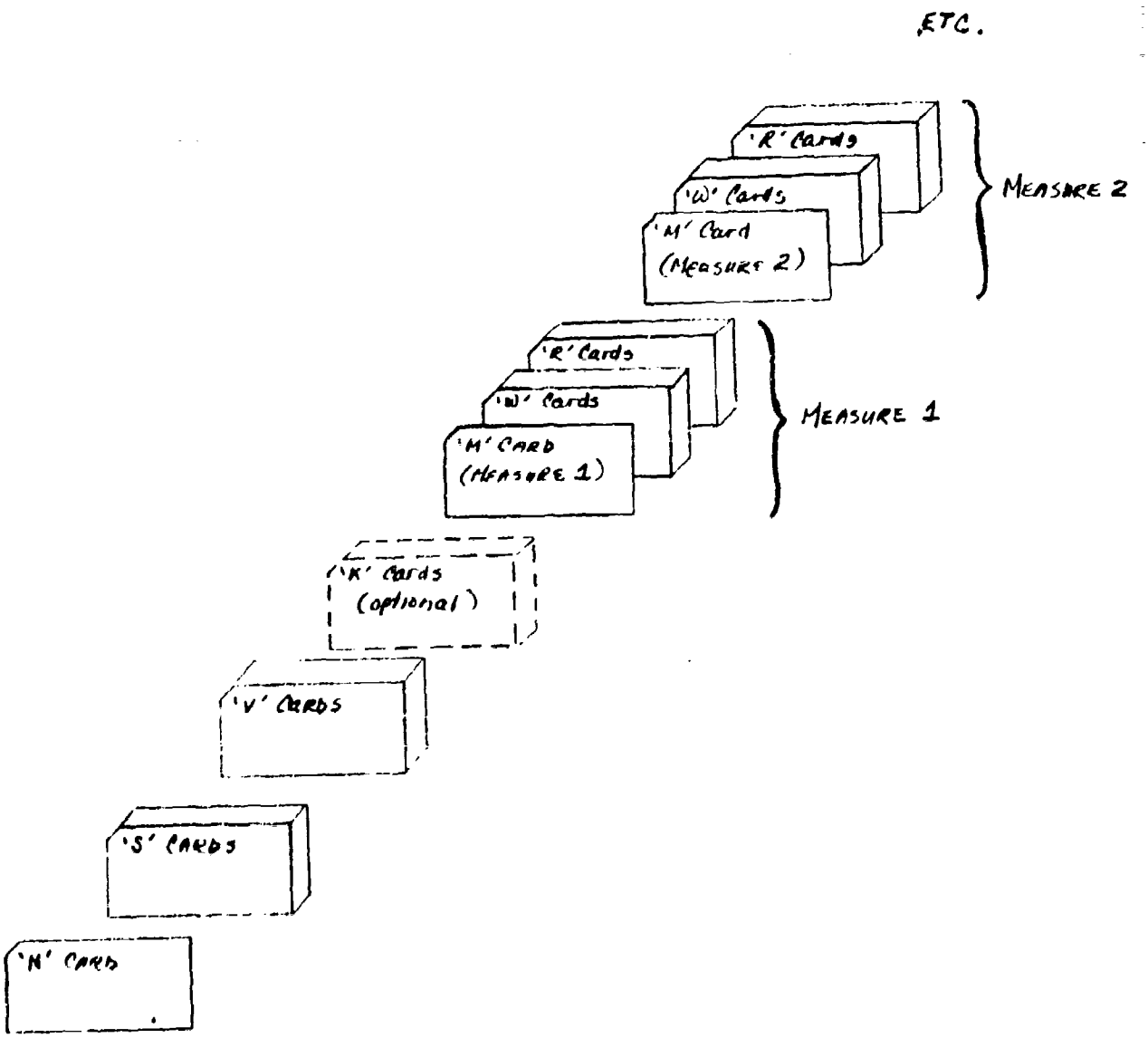
Following these parameter and formatting cards, the factors and subfactors are to be input. These cards should be grouped by measure.

Card Type M - Function - contains the abbreviated measure name (10 characters) which will appear on the output report. The card also contains the measure weight. One 'M' card is required for each measure.

Card Type W - Function - contains the weights (by vessel) for each factor, subfactor. Cards should be in factor sequence.

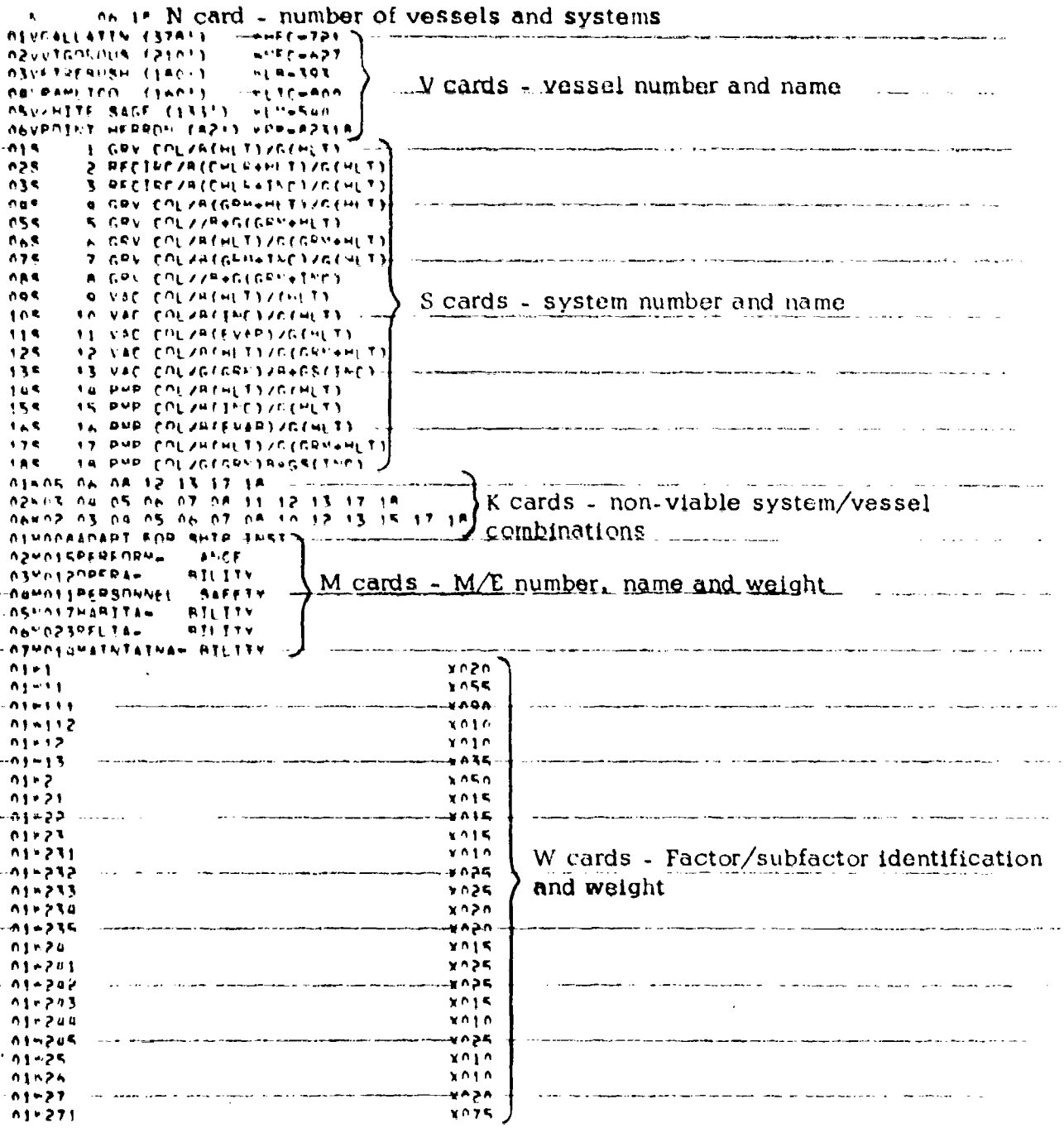
Card Type R - Function - contains the ratings (by system) for each factor, subfactor. Cards should be in factor sequence.

RECOMMENDED SEQUENCE OF INPUT DATA



SAMPLE PROBLEM

The sample problem included in this section consists of the 18 viable candidate systems for the six vessels included in this study. This section contains a listing of the input (card images), a pictorial layout of the job stream, a list of the actual JCL, and the resulting output report.


N card - number of vessels and systems
V cards - vessel number and name
S cards - system number and name
K cards - non-viable system/vessel combinations
M cards - M/E number, name and weight
W cards - Factor/subfactor identification and weight

01*272	X025
01*3	X030
01*31	X010
01*32	X010
01*33	X015
01*34	X040
01*35	X025
01*351	X025
01*352	X020
01*353	X035
01*358	X010
01*355	X010
02*1	X015
02*11	X030
02*12	X025
02*13	X045
02*2	X025
02*21	X040
02*22	X010
02*3	X005
02*31	X050
02*311	X040
02*312	X010
02*32	X020
02*321	X065
02*322	X035
02*33	X030
02*331	X075
02*332	X025
02*4	X015
02*41	X040
02*42	X010
02*5	X015
02*51	X065
02*52	X015
02*53	X010
02*58	X010
02*6	X015
02*61	X040
02*62	X060
02*7	X010
02*71	X075
02*72	X025
03*1	X020
03*11	X035
03*12	X030
03*13	X020
03*18	X015
03*2	X050
03*21	X040
03*22	X020
03*23	X005
03*24	X005
03*25	X010
03*26	X030
03*3	X030
03*31	X050
03*32	X030
03*33	X020
04*1	X030

W cards

W cards

W card

R cards - elementary factor/ subfactor identification and ratings for each system/ vessel combination

All remaining cards

```
010235  05 080 080 080 100 100 100 100 100          ?
010235  06 100 000 000 000 000 000 000 000 000 0001
010235  0A 080 000 000 080 000 080 000 000          ?
010201  01 080 080 080 080 000 000 080 000 080 0001
010241  0C 000 000 000 000 000 030 000 000          ?
010241  02 100 080 000 000 000 000 000 000 080 0001
010241  02 000 000 000 100 080 030 000 000          ?
010241  03 000 080 080 080 080 080 080 080 080 0001
010241  03 080 080 080 000 080 080 080 080          ?
010241  08 080 080 080 080 080 080 080 080 080 0001
010241  0A 080 080 080 080 080 080 080 080          ?
010241  05 100 080 080 080 100 080 080 080 100 0001
010241  05 080 080 080 080 080 080 080 080          ?
010241  06 100 000 000 000 000 000 000 000 030 0001
010241  06 030 000 000 100 000 080 000 000          ?
010242  01 100 050 050 050 000 000 050 000 050 0501
010242  01 000 000 000 050 050 000 000 000          ?
010242  02 100 050 000 000 000 000 000 000 050 0501
010242  02 000 000 000 050 000 000 000 000          ?
010242  03 050 050 050 050 050 050 050 050 050 0501
010242  03 050 050 050 050 050 050 050 050          ?
010242  08 000 000 000 000 000 000 000 000 050 0501
010242  0A 050 050 050 050 050 050 050 050          ?
010242  05 100 050 050 050 050 050 050 050 050 0501
010242  05 050 050 050 050 050 050 050 050          ?
010242  06 100 000 000 000 000 000 000 000 050 0001
010242  06 050 000 000 050 000 050 000 000          ?
010243  01 100 100 100 000 000 000 000 000 000 0001
010243  01 000 000 003 100 000 000 000 000          ?
010243  02 100 100 000 000 000 000 000 000 100 1001
010243  02 000 000 000 100 000 000 000 000          ?
010243  03 100 100 100 100 100 100 100 100 100 1001
010243  03 100 100 100 100 100 100 100 100          ?
010243  08 000 100 100 100 100 100 100 100 100 1001
010243  0A 100 100 100 100 100 100 100 100          ?
010243  05 100 000 000 000 000 000 000 000 000 0001
010243  05 000 000 000 000 000 000 000 000 000 0002
010243  06 100 000 000 000 000 000 000 000 000 0001
010243  06 000 000 000 100 000 000 000 000 000 0002
010244  01 100 000 000 000 000 000 000 000 000 0001
010244  01 000 000 000 000 000 000 000 000          ?
010244  02 100 000 000 000 000 000 000 000 000 0001
010244  02 000 000 000 000 000 000 000 000          ?
010244  03 100 000 000 000 000 000 000 000 000 0001
010244  03 000 000 000 100 000 000 000 000          ?
010244  08 000 000 000 000 000 000 000 000 000 0001
010244  0A 000 000 000 000 000 000 000 000          ?
010244  05 100 000 000 000 000 000 000 000 000 0001
010244  05 000 000 000 000 000 000 000 000          ?
010244  06 100 000 000 000 000 000 000 000 000 0001
010244  06 000 000 000 100 000 000 000 000          ?
010245  01 100 100 000 100 000 000 000 000 100 0001
010245  01 100 000 000 100 000 100 000 000          ?
010245  02 100 100 000 000 000 000 000 000 100 0001
010245  02 000 000 000 100 000 100 000 000          ?
010245  03 100 100 000 100 100 100 000 000 100 0001
010245  03 100 100 000 100 000 100 100 000          ?
010245  08 100 100 020 100 100 100 020 020 100 0201
010245  06 100 100 020 100 020 100 100 020          ?
010245  05 100 100 020 100 100 100 000 000 100 0201
```

01R31	05	100	100	100	100	100	100	100	100			2
01R31	06	100	000	000	000	000	000	000	000	000	000	0001
01R31	06	000	000	000	100	000	000	000	000			2
01R32	01	100	100	100	100	000	000	100	000	100	100	1001
01R32	01	100	000	000	100	100	100	000	000			2
01R32	02	100	100	000	000	000	000	000	000	000	100	1001
01R32	02	000	000	000	100	100	100	000	000			2
01R32	03	100	100	100	100	100	100	100	100	100	100	1001
01R32	03	100	100	100	100	100	100	100	100			2
01R32	04	070	070	070	070	070	070	070	070	070	070	0701
01R32	04	070	070	070	070	070	070	070	070			2
01R32	05	100	100	100	070	070	070	070	100	100	100	1001
01R32	05	100	100	100	100	100	100	070	100			2
01R32	06	100	000	000	000	000	000	000	000	000	000	0001
01R32	06	000	000	000	100	000	000	000	000			2
01R33	01	100	100	100	100	000	000	100	000	100	100	1001
01R33	01	100	000	000	100	100	100	000	000			2
01R33	02	100	100	000	000	000	000	000	000	100	099	1991
01R33	02	000	000	000	100	099	100	000	000			2
01R33	03	100	100	097	100	100	100	096	096	097	093	1931
01R33	03	097	097	093	097	093	097	097	093			2
01R33	04	000	000	000	000	000	000	000	000	000	000	0001
01R33	04	000	000	000	000	000	000	000	000			2
01R33	05	100	100	100	100	100	100	100	100	099	099	1991
01R33	05	099	099	099	099	099	099	099	099			2
01R33	06	100	000	000	000	000	000	000	000	000	093	0091
01R33	06	093	000	000	093	000	093	000	000			2
01R34	01	080	080	080	080	000	000	080	000	080	080	0801
01R34	01	080	000	000	080	080	080	000	000			2
01R34	02	100	100	000	000	000	000	000	000	100	100	1001
01R34	02	000	000	000	100	100	100	000	000			2
01R34	03	100	100	100	080	080	080	080	080	080	040	0401
01R34	03	040	040	040	100	080	040	000	000			2
01R34	04	080	080	080	080	080	080	080	080	080	080	0801
01R34	04	080	080	080	080	080	080	080	080			2
01R34	05	100	100	100	100	100	100	100	100	100	100	1001
01R34	05	100	100	100	100	100	100	100	100			2
01R34	06	100	000	000	000	000	000	000	000	080	000	0001
01R34	06	080	000	000	080	000	080	000	000			2
01R351	01	099	097	096	088	000	000	073	000	062	059	1591
01R351	01	000	000	000	099	096	037	000	000			2
01R351	02	095	099	000	000	000	000	000	000	005	000	1001
01R351	02	000	000	000	097	092	003	000	000			2
01R351	03	099	098	097	079	059	059	062	041	071	067	1671
01R351	03	000	030	034	099	095	028	058	061			2
01R351	04	100	097	096	025	025	025	009	009	091	075	1751
01R351	04	024	016	000	099	083	032	025	008			2
01R351	05	099	095	094	049	049	049	049	032	073	055	1551
01R351	05	000	023	005	063	081	025	048	031			2
01R351	06	099	000	000	000	000	000	000	000	041	000	1001
01R351	06	000	000	000	096	000	055	000	000			2
01R352	01	100	100	025	100	000	000	000	000	100	003	1031
01R352	01	100	000	000	100	003	100	000	000			2
01R352	02	100	100	000	000	000	000	000	000	100	000	1001
01R352	02	000	000	000	100	000	100	000	000			2
01R352	03	100	100	025	100	100	100	000	000	100	000	1001
01R352	03	100	100	000	100	000	100	100	100			2
01R352	04	100	100	025	100	100	100	000	000	100	000	1001
01R352	04	100	100	000	100	000	100	100	000			2
01R352	05	100	100	025	100	100	100	000	000	100	000	1001

01R352	05	100	100	000	100	000	100	100	000			2
01R352	06	100	000	000	000	000	000	000	000	100	000	1
01R352	06	100	000	000	100	000	100	000	000			2
01R353	01	100	100	100	100	000	000	100	000	000	000	1
01R353	01	000	000	000	003	003	003	000	000			2
01R353	02	100	100	000	000	000	000	000	000	000	000	1
01R353	02	000	000	000	008	008	008	000	000			2
01R353	03	100	100	100	100	100	100	100	100	000	000	1
01R353	03	000	000	000	009	009	009	009	009			2
01R353	04	100	100	100	100	100	100	100	100	000	000	1
01R353	04	000	000	000	000	000	000	000	000			2
01R353	05	100	100	100	100	100	100	100	100	000	000	1
01R353	05	000	000	000	000	000	000	000	000			2
01R353	06	100	000	000	000	000	000	000	000	000	000	1
01R353	06	000	000	000	000	000	000	000	000			2
01R354	01	000	082	100	092	000	000	066	000	071	092	1
01R354	01	052	000	000	068	092	052	000	000			2
01R354	02	000	075	000	000	000	000	000	000	066	088	1
01R354	02	000	000	000	019	088	031	000	000			2
01R354	03	019	085	100	093	074	000	090	090	077	098	1
01R354	03	086	077	090	074	098	086	074	090			2
01R354	04	019	085	100	093	074	000	095	095	075	095	1
01R354	04	092	075	095	074	095	092	074	095			2
01R354	05	000	081	100	091	068	000	048	048	072	048	1
01R354	05	029	072	048	068	048	029	015	048			2
01R354	06	000	000	000	000	000	000	000	000	057	000	1
01R354	06	019	000	000	044	000	019	000	000			2
01R355	01	100	100	100	000	000	000	000	000	100	100	1
01R355	01	100	000	000	100	100	100	000	000			2
01R355	02	100	100	000	000	000	000	000	000	100	100	1
01R355	02	000	000	000	100	100	100	000	000			2
01R355	03	100	100	100	050	000	000	050	000	100	100	1
01R355	03	100	000	050	100	100	100	000	050			2
01R355	04	100	100	100	000	000	000	000	000	100	100	1
01R355	04	100	000	000	100	100	100	000	000			2
01R355	05	100	100	100	000	000	000	000	000	100	100	1
01R355	05	100	000	000	100	100	100	000	000			2
01R355	06	100	000	000	000	000	000	000	000	100	000	1
01R355	06	100	000	000	100	000	100	000	000			2
02R11	01	100	099	086	098	000	000	076	000	091	073	1
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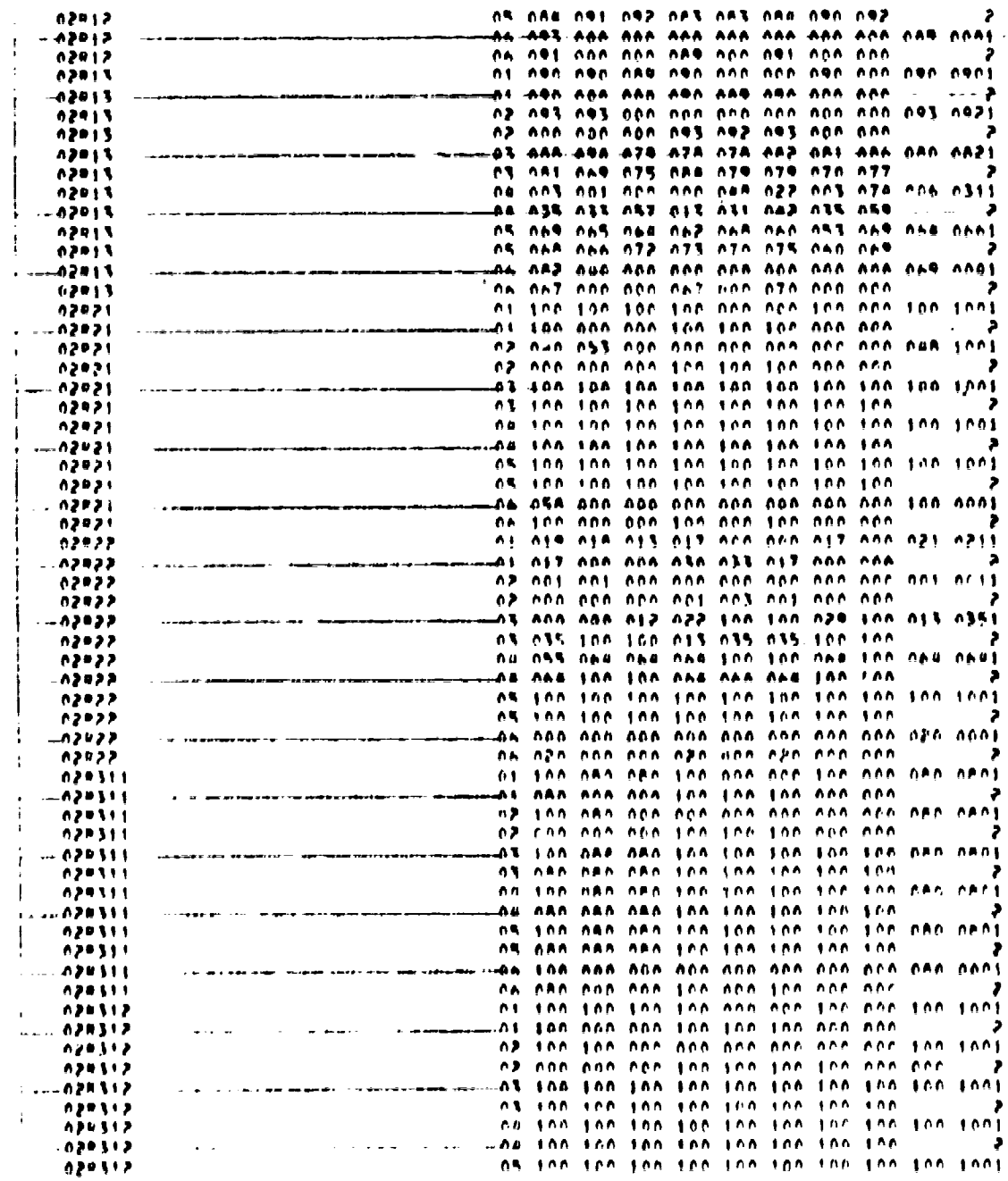

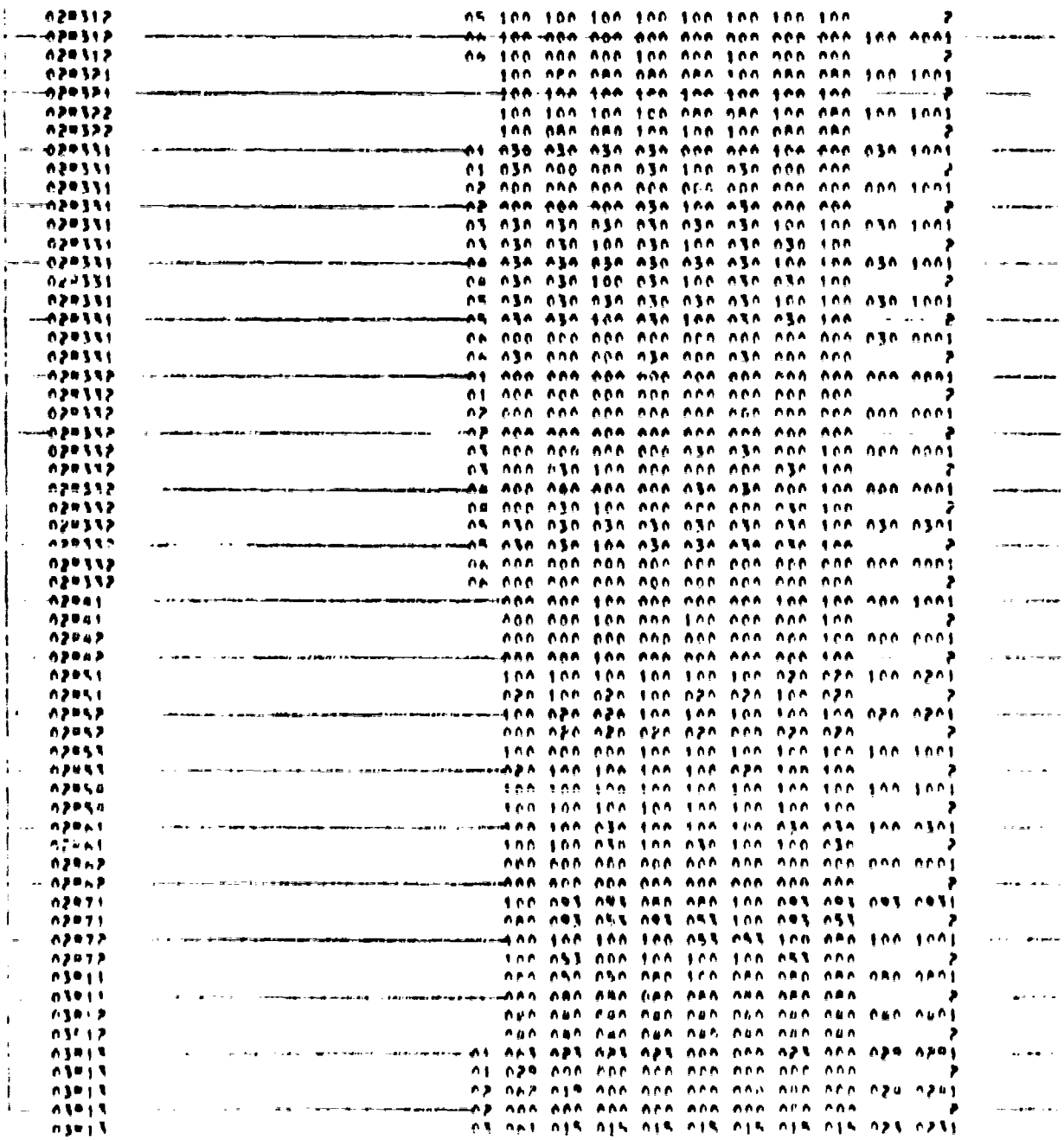

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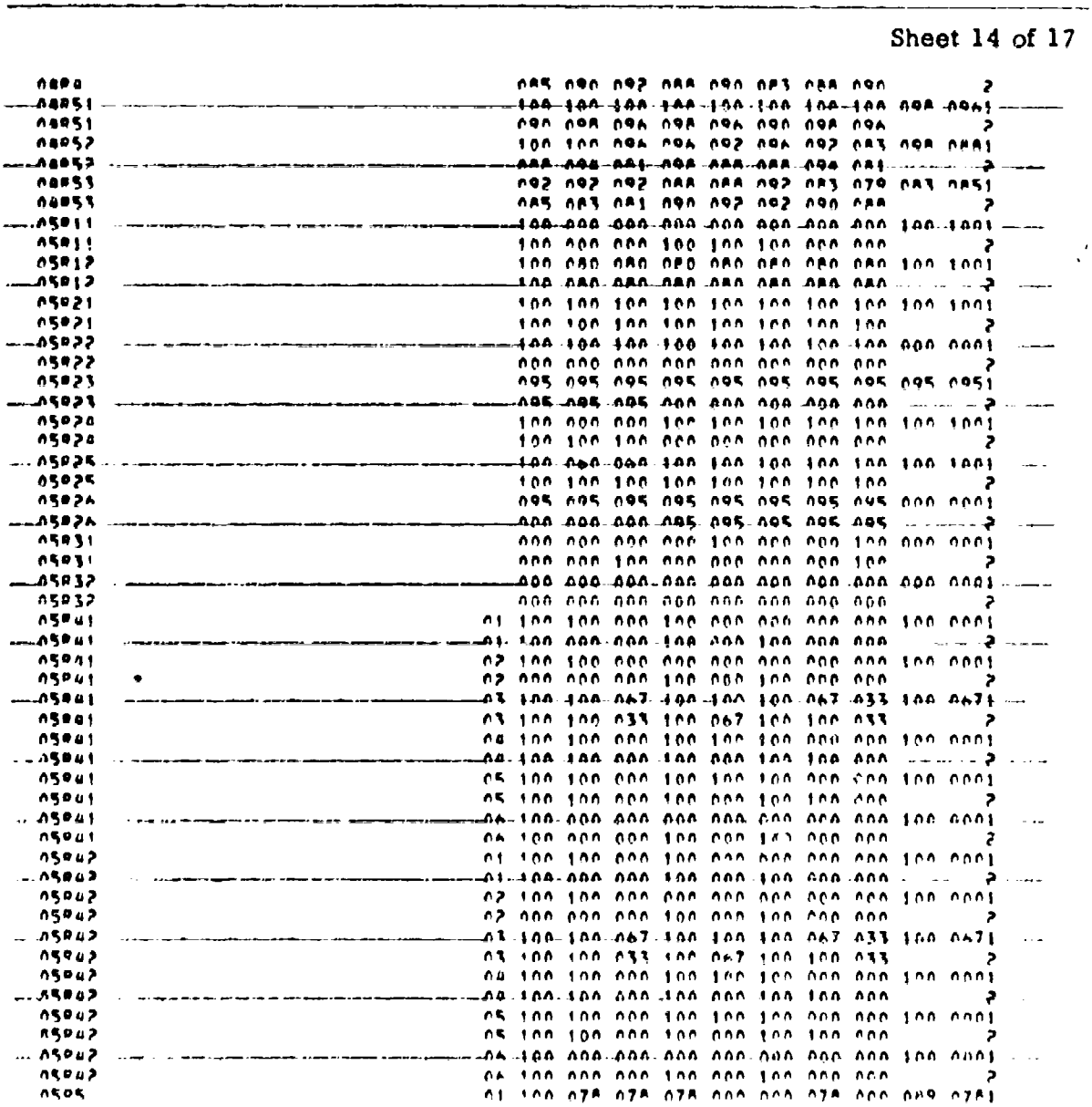

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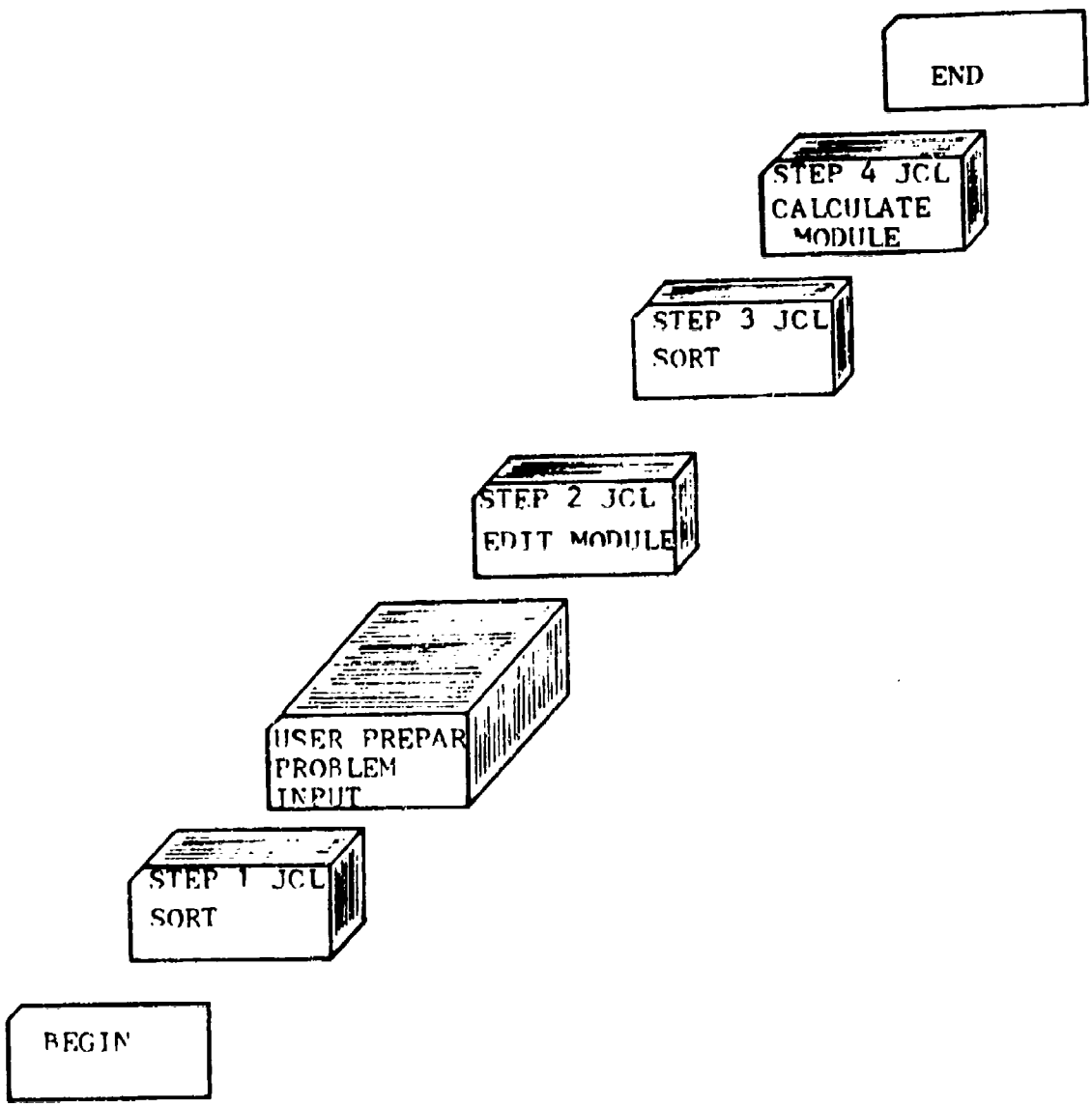
07932	05	017	032	055	000	025	000	015	040	040	0551
07932	05	055	023	063	021	036	036	004	044		2
07932	06	014	000	000	000	000	000	000	000	014	0001
07932	06	036	000	000	000	000	022	000	000		2
07933		100	100	100	100	100	100	100	100	100	1001
07933		100	100	100	100	100	100	100	100		2
0794		100	075	075	075	075	075	075	075	075	0751
0794		075	075	075	075	075	075	075	075		2

Job Stream

This section contains both a schematic diagram (see following page) and a card image of the actual Job Control Language (JCL) used to run the sample problem. The user prepared input (part of Step 1) should be sequenced as previously described.

JOB STREAM INPUT



Actual JCL

```
//STEP1   EXEC SORT,PARM.SORT='CORE=060000,MSG=AP',REGION=70K
//SYSOUT    DD SYSOUT=A
//SORTIN    DD *,DCB=BLKSIZE=80
    {
      USER PREPARED INPUT
/*
//SCRTWKC1 DD UNIT=SYSDA,SPACE=(CYL,(2,1))
//SORTWKO2 DD UNIT=SYSDA,SPACE=(CYL,(2,1))
//SCRTWKC3 DD UNIT=SYSDA,SPACE=(CYL,(2,1))
//SORTWKO4 DD UNIT=SYSDA,SPACE=(CYL,(2,1))
//SCRTWKO5 DD UNIT=SYSDA,SPACE=(CYL,(2,1))
//SORTWKO6 DD UNIT=SYSDA,SPACE=(CYL,(2,1))
//SCRTOUT  DD DSN=&FACTOR1,DISP=(NEW,PASS),UNIT=SYSDA,
//         DCB=(RECFM=FB,LRECL=80,BLKSIZE=800),SPACE=(CYL,(2,1))
//SORT.SYSIN DD *
 SORT FIELDS=(1,2,A,4,5,C,38,2,A,3,1,D,80,1,A),FORMAT=BI
/*


//STEP2   EXEC PGM=CGWM1
//STEPLIB DD DSN=BIDS.TEST,DISP=SHR
//SYSUDUMP DD SYSOUT=A
//SYSOUT    DD SYSOUT=A
//PRINTER   DD SYSOUT=A,DCB=BLKSIZE=1330
//FACTORS   DD DSN=&FACTOR1,DISP=(OLD,PASS),
//             DCB=(RECFM=FB,LRECL=80,BLKSIZE=800)
//SYSIN     DD DSN=BIDS.OLYSLASH,DISP=SHR


//STEP3   EXEC SORT,PARM.SORT='CORE=060000,MSG=AP',REGION=70K
//SYSOUT    DD SYSOUT=A
//SORTIN    DD DSN=&FACTOR1,DISP=(OLD,PASS),UNIT=SYSDA,
//         DCB=(RECFM=FB,LRECL=80,BLKSIZE=800),SPACE=(CYL,(2,1))
//SORTWKO1 DD UNIT=SYSDA,SPACE=(CYL,(2,1))
//SCRTWKC2 DD UNIT=SYSDA,SPACE=(CYL,(2,1))
//SCRTWKO3 DD UNIT=SYSDA,SPACE=(CYL,(2,1))
//SORTWKC4 DD UNIT=SYSDA,SPACE=(CYL,(2,1))
//SORTWKO5 DD UNIT=SYSDA,SPACE=(CYL,(2,1))
//SCRTWKC6 DD UNIT=SYSDA,SPACE=(CYL,(2,1))
//SORTOUT  DD DSN=&FACTOR2,DISP=(NEW,PASS),UNIT=SYSDA,
//         DCB=(RECFM=FB,LRECL=80,BLKSIZE=800),SPACE=(CYL,(2,1))
//SORT.SYSIN DD *
 SORT FIELDS=(3,1,A,1,2,A,4,5,D,38,2,A,80,1,A),FORMAT=BI
/*


//STEP4   EXEC PGM=CGWM2
//STEPLIB DD DSN=BIDS.TEST,DISP=SHR
//SYSUDUMP DD SYSOUT=A
//SYSOUT    DD SYSOUT=A
//PRINTER   DD SYSOUT=A,DCB=BLKSIZE=1330
//SYSIN     DD DSN=BIDS.OLYSLASH,DISP=SHR
//FACTORIN DD DSN=&FACTOR2,DISP=(OLD,DELETE),
//             DCB=(RECFM=FB,LRECL=80,BLKSIZE=800)
//
```

Output Report

EFFECTIVENESS OF RADIOACTIVE WASTE WATER MANAGEMENT SYSTEMS FOR SELECTED GAS TURBINE VESSELS

VESSEL: GALLATIN (DE 1034) SHEET-121

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* * * * * MEASURE OF EFFECTIVENESS (AND ASSOCIATED WEIGHT) * * * * * *

SYSTEM NO. (WT)	SURFACE SHIP SURVIVABILITY (.09)	PERFORMANCE (.15)	OPERABILITY (.14)	PERSONNEL SAFETY (.11)	MAINTAINABILITY (.17)	RELIABILITY (.23)	MAINTAINABILITY (.10)	OVERALL EFFECTIVENESS (1.0)
1 GEN COL/SLT/S(WLT)	48	72	91	95	75	96	92	77
2 REC/REC/S(CM PAWLT)/OS(WLT)	81	67	52	94	91	87	73	77
3 REC/REC/S(CM PAWLT)/S(WLT)	78	76	57	92	76	93	79	77
4 GEN COL/INC(PAWLT)/S(WLT)	77	73	83	96	64	95	79	77
5 GEN COL/RB+S(GPM+WLT)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6 GEN COL/SOLT)/SCE PAWLT)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7 GEN COL/LOW+INC)/S(WLT)	83	72	71	90	63	93	80	77
8 GEN COL/SL+S(GPM+WLT)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9 VAR COL/SLT/S(WLT)	72	69	95	95	71	66	53	66
10 VAR COL/RE(INC)/S(WLT)	69	70	53	92	55	93	58	67
11 VAR COL/SLSVAP)/S(WLT)	65	58	64	91	65	62	41	59
12 VAR COL/SLWLT)/S(PAWLT)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
13 VAR COL/S(GPM)/R+S(WLT)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
14 PWR COL/BIWLT)/S(WLT)	71	70	86	93	67	76	67	72
15 PWR COL/RE(INC)/S(WLT)	67	69	74	91	50	86	69	75
16 PWR COL/RISVAP)/S(WLT)	66	60	85	89	60	76	61	67
17 PWR COL/BIWLT)/GE(PAWLT)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
18 PWR COL/S(GPM)+S(INC)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

16/02/77 EFFECTIVENESS OF CANDIDATE WASTE WATER MANAGEMENT SYSTEMS FOR SELECTED COAST GUARD VESSELS PAGE 2

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VESSEL VIGOROUS (210') VMEC-627

* * * * * * MEASURE OF EFFECTIVENESS (AND ASSOCIATED WEIGHT) * * * * * *

SYSTEM NO. NAME	BOARD FOR SHIP DIST (3)	PERFORM-ANCE (15)	OPERA-BILITY (17)	PERSONNEL SAFETY (11)	HABITA-BILITY (17)	RELIA-BILITY (23)	MAINTAINA-BILITY (14)	OVERALL EFFECTIVENESS (1)
1 GRV COL/B(HLT)/G(HLT)	84	54	91	95	75	95	93	84
2 RECIRC/B(CHLR+HLT)/G(HLT)	69	56	54	80	51	83	81	69
3 RECIRC/B(CHLR+INC)/G(HLT)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4 GRV COL/B(GRM+HLT)/G(HLT)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5 GRV COL/B+G(GRM+HLT)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6 GRV COL/B(HLT)/G(GRM+HLT)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7 GRV COL/B(GRM+INC)/G(HLT)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8 GRV COL/B+G(GRM+INC)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9 VAC COL/B(HLT)/G(HLT)	65	57	65	95	71	43	50	61
10 VAC COL/B(INC)/G(HLT)	63	70	52	88	55	31	50	55
11 VAC COL/B(EVAP)/G(HLT)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12 VAC COL/B(HLT)/G(GRM+HLT)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
13 VAC COL/G(GRM)/B+G(INC)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
14 PMP COL/B(HLT)/G(HLT)	76	69	86	93	67	80	53	74
15 PMP COL/B(INC)/G(HLT)	62	68	74	87	50	67	50	65
16 PMP COL/B(EVAP)/G(HLT)	59	60	86	89	60	79	44	69
17 PMP COL/B(HLT)/G(GRM+HLT)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
18 PMP COL/G(GRM)/B+G(INC)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

[illegible] PAGE 3

EFFECTIVENESS OF CANDIDATE WASTE WATER MANAGEMENT SYSTEMS FOR EFFECTED [illegible] SHIPS VESSELS

VESSEL FIREBUSH (IRON) [illegible]

* * * * * * MEASURE OF EFFECTIVENESS (AND ASSOCIATED WEIGHT) * * * * * *

SYSTEM NO. NAME	SHIP FOR SHIP INST (0)	PERFORMANCE (15)	OPERABILITY (17)	PERSONNEL SAFETY (11)	HABITABILITY (17)	RELIABILITY (21)	MAINTAINABILITY (14)	OVERALL EFFECTIVENESS (%)
1 GRV COL/[illegible]	62	71	[illegible]	95	25	95	93	86
2 RECIRC/[illegible]	63	67	51	38	51	82	78	71
3 RECIRC/[illegible]	77	75	51	32	47	77	76	69
4 GRV COL/[illegible]	81	69	76	94	54	24	78	76
5 GRV COL/[illegible]	73	70	73	94	73	40	76	79
6 GRV COL/[illegible]	61	71	73	95	70	29	76	79
7 GRV COL/[illegible]	74	71	67	80	53	81	79	73
8 GRV COL/[illegible]	73	75	62	77	63	74	74	71
9 VAC COL/[illegible]	73	68	73	95	71	46	48	64
10 VAC COL/[illegible]	53	69	50	92	65	31	47	57
11 VAC COL/[illegible]	61	57	70	91	65	45	35	58
12 VAC COL/[illegible]	54	68	57	95	56	37	36	56
13 VAC COL/[illegible]	53	67	52	69	63	26	37	52
14 PRD COL/[illegible]	67	69	81	93	67	85	67	75
15 PRD COL/[illegible]	62	57	60	91	60	73	57	69
16 PRD COL/[illegible]	60	59	80	89	60	84	52	70
17 PRD COL/[illegible]	59	60	64	74	52	70	51	69
18 PRD COL/[illegible]	57	60	61	89	50	60	53	64

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SYSTEM NO. NAME	ASSET RISK SHIP INST (.49)	PERFORM-ANCE (.153)	SUPPORT-ABILITY (.121)	PERSONNEL SAFETY (.113)	MOBILITY-ABILITY (.179)	RELIA-BILITY (.231)	MAINTAINA-BILITY (.151)	OVERALL EFFECTIVENESS (1.0)
1	55	59	67	95	85	93	96	81
2	61	66	61	89	51	76	69	64
3	59	69	67	92	76	69	71	61
4	56	61	71	95	58	83	65	69
5	57	56	76	96	73	68	73	73
6	57	65	76	95	60	89	73	72
7	55	67	63	90	63	71	69	63
8	56	71	69	72	58	65	72	65
9	71	76	73	95	71	67	51	64
10	73	63	67	92	55	79	50	55
11	75	56	76	91	65	63	66	60
12	76	63	63	95	56	56	32	64
13	71	69	51	73	59	72	51	59
14	69	63	61	93	63	76	53	71
15	66	61	73	91	59	76	59	67
16	66	59	83	89	63	73	69	66
17	65	66	69	96	63	61	66	63
18	63	68	67	89	56	69	63	59

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[illegible] EFFECTIVENESS OF CANDIDATE WASTE WATER MANAGEMENT SYSTEMS FOR SELECTED COAST GUARD VESSELS PAGE 5

VESSEL WHITE SAGE (1335) WLM-544

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* * * * * * MEASURE OF EFFECTIVENESS (AND ASSOCIATED WEIGHT) * * * * * *

SYSTEM NO. NAME	ADAPT FOR SHIP INST (10)	MAINTENANCE (15)	OPERABILITY (17)	GEN. PERSONNEL SAFETY (11)	MARITABILITY (17)	RELIABILITY (23)	MAINTAINABILITY (14)	OVERALL EFFECTIVENESS (5)
1 GRV COL/B(HLT)/G(HLT)	95	73	87	95	75	96	85	86
2 RECIRC/B(CHLR+HLT)/G(HLT)	82	68	45	85	51	76	69	68
3 RECIRC/B(CHLR+INC)/G(HLT)	83	76	47	88	36	73	70	65
4 GRV COL/B(GRM+HLT)/G(HLT)	84	83	70	96	58	59	70	76
5 GRV COL//B+G(GRM+HLT)	89	59	72	96	73	76	73	74
6 GRV COL/B(HLT)/G(GRM+HLT)	78	70	71	95	69	85	71	76
7 GRV COL/B(GRM+INC)/G(HLT)	85	72	67	73	63	77	73	68
8 GRV COL//B+G(GRM+INC)	86	74	62	50	58	71	76	69
9 VAC COL/B(HLT)/G(HLT)	74	59	65	95	71	61	51	65
10 VAC COL/B(INC)/G(HLT)	72	73	58	94	55	27	50	56
11 VAC COL/G(EVAP)/G(HLT)	73	58	69	51	65	38	45	59
12 VAC COL/B(HLT)/G(GRM+HLT)	74	68	63	95	54	31	41	56
13 VAC COL/G(GRM)/B+G(INC)	69	67	49	73	58	19	53	51
14 PMP COL/B(HLT)/G(HLT)	74	73	90	93	67	66	47	70
15 PMP COL/G(INC)/G(HLT)	72	65	69	91	59	57	49	67
16 PMP COL/B(EVAP)/G(HLT)	74	61	81	93	69	63	47	66
17 PMP COL/B(HLT)/G(GRM+HLT)	73	63	69	92	52	58	43	62
18 PMP COL/G(GRM)/B+G(INC)	77	67	63	69	37	46	47	54

VESSEL POINT HENRON (52') WPB-82312*

* * * * * * MEASURE OF EFFECTIVENESS (AND ASSOCIATED WEIGHT) * * * * * *

SYSTEM NO. NAME	ASSET FOR SHIP (WT)	PERFORM-ANCE (WT)	AVAIL-ABILITY (WT)	PERSONNEL SAFETY (WT)	HABITA-BILITY (WT)	RELIA-BILITY (WT)	MAINTAINA-BILITY (WT)	OVERALL EFFECTIVENESS (E.E.)
1 DAV COL/RIGHT)/G(WHT)	45	61	83	95	75	91	85	82
2 RECIEF/R(CHERAM)/G(WHT)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3 RECIEF/R(CHERAM)/G(WHT)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4 GRV COL/RIGHT)/G(WHT)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5 GRV COL/RIGHT)/G(WHT)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6 GRV COL/RIGHT)/G(WHT)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7 GRV COL/RIGHT)/G(WHT)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8 GRV COL/RIGHT)/G(WHT)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9 VAC COL/RIGHT)/G(WHT)	62	67	65	95	71	34	44	60
10 VAC COL/RIGHT)/G(WHT)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11 VAC COL/RIGHT)/G(WHT)	51	57	67	93	65	36	39	55
12 VAC COL/RIGHT)/G(WHT)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
13 VAC COL/RIGHT)/G(WHT)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
14 PAP COL/RIGHT)/G(WHT)	71	69	74	93	67	85	61	71
15 PAP COL/RIGHT)/G(WHT)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
16 PAP COL/RIGHT)/G(WHT)	62	59	76	93	60	72	69	66
17 PAP COL/RIGHT)/G(WHT)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
18 PAP COL/RIGHT)/G(WHT)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

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PROGRAM DESCRIPTION

The computer program for quantifying the effectiveness of candidate system/vessel combination is written in ANSI COBOL. It consists of two sorts and two program modules.

The first sort reads as input the complete user prepared data for the problem. The output of the sort is a temporary disk data set which is deleted at the end of the entire run. This data set (&FACTOR1) is input into the first program module, the edit.

The edit program module (CGWM1) reads each card image from the temporary data set. The first edit performed is on the type of input. Column three of the input data prepared by the user contains an alphabetic character indicating the type of input. If the entry in the input card is different than those allowed, the error message 'Invalid Card Type' and the card image is printed on the reject report.

Numerous edits are performed on the factors and subfactors contained in the weight and rating input cards. Each factor or subfactor is tested for numeric and is also checked to be in the legitimate range of zero to one-hundred. If these tests are failed, the error messages 'Non-Numeric Factor', 'Factor Less than Zero , or 'Factor Greater than One-Hundred' are output along with the image of the card. Each rating card, in addition to the above editing, must also match a weight card, which is processed immediately prior to it. If the rating card does not match, the error message 'Unmatched Rating Card' and the card image are output. When the level of the weight factors/subfactors changes, no rating factor/subfactor is required. An additional edit is performed to check this and the error message 'Invalid Rating Card' is printed if a rating card is present.

One final edit is performed on the weight card factors and subfactors. As each card is processed, the weights are accumulated. When

the factor/subfactor level changes, the accumulated weights are checked to determine if they add to one hundred. If they do not, the error message 'Factors Not 100' is printed along with the related measure number, vessel number, and level.

At the conclusion of the edit module, the temporary data set which was used as input, is resorted and a second temporary data set (&FACTOR2) is created. This data set becomes the input file to the calculation module (CGWM2). Although the edit module performs most of the editing functions, a few additional edits are performed in this module. These edits are performed before the calculations are begun and, if any edit fails, the module is aborted. The following areas are edited:

- Measure Cards
- System Cards
- Vessel Cards

a) Measure Card Editing (Card Type M)

The weight assigned to each measure is edited for the following criteria. It must be numeric, less than or equal to 100, and greater than or equal to zero. If any of these edit tests are failed, an appropriate message is printed and the module aborted. The measure weights are accumulated, and after all of the input data has been processed, the accumulated weight is checked to see if it is one-hundred. If it is not, the module is aborted.

The limit on the number of measures allowed in the program is 15. The measure number on each measure card processed is checked. It must fall in the range of 01 to 15. An error message is printed and the run aborted if it is not.

b) System Card Editing (Card Type S)

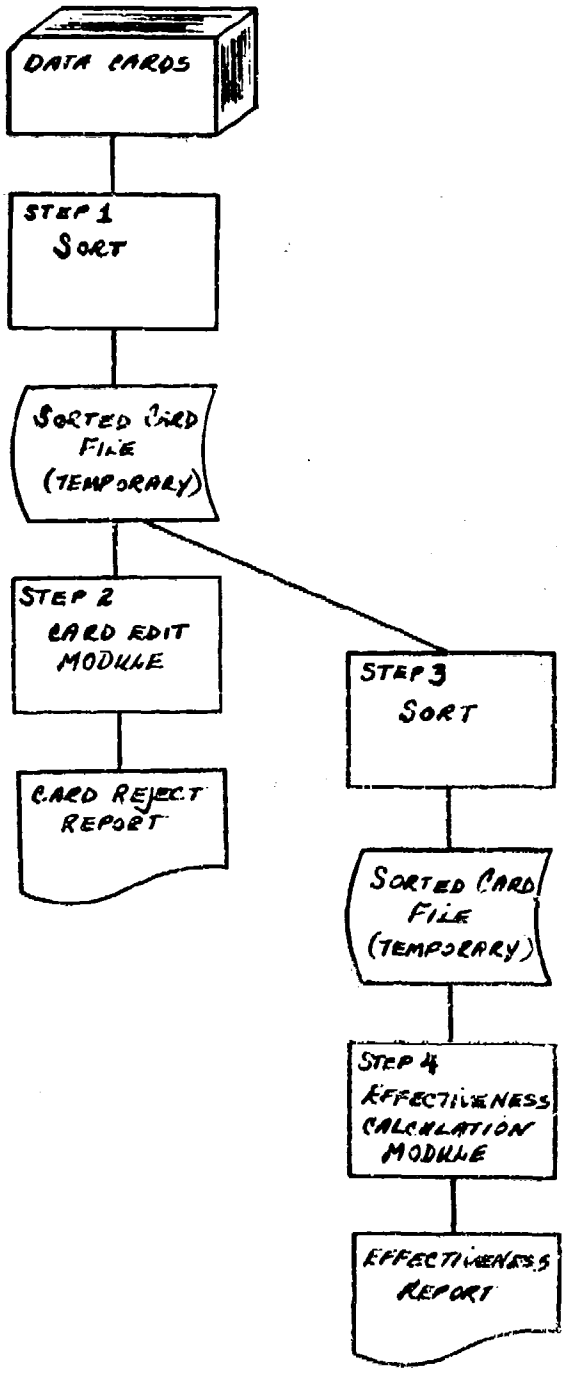
The maximum number of systems allowed in the program is 30. The system number on each system card processed is edited. It must fall within the valid boundaries of 01 to 30. If it does not, an error message is printed and the module aborted.

c) Vessel Card Editing (Card Type V)

A similar type edit is performed on vessel cards as is performed on the system cards. The maximum allowable number of vessels is 20. If the vessel number on the vessel card is outside the range of 01 to 20, an error message is printed and the run aborted.

The calculation module initially reads all of the input data, performs the above edits, and tables the data read. The module then begins the calculation of the effectiveness of each system. This is performed for each measure and for the overall effectiveness for each system for each vessel. The measures of effectiveness are calculated by system within vessel. Each vessel appears on a separate page. If a system is not applicable for a particular vessel, the measures of effectiveness ratings are masked out and the symbol N/A will be printed instead of the rating for the measure of effectiveness.

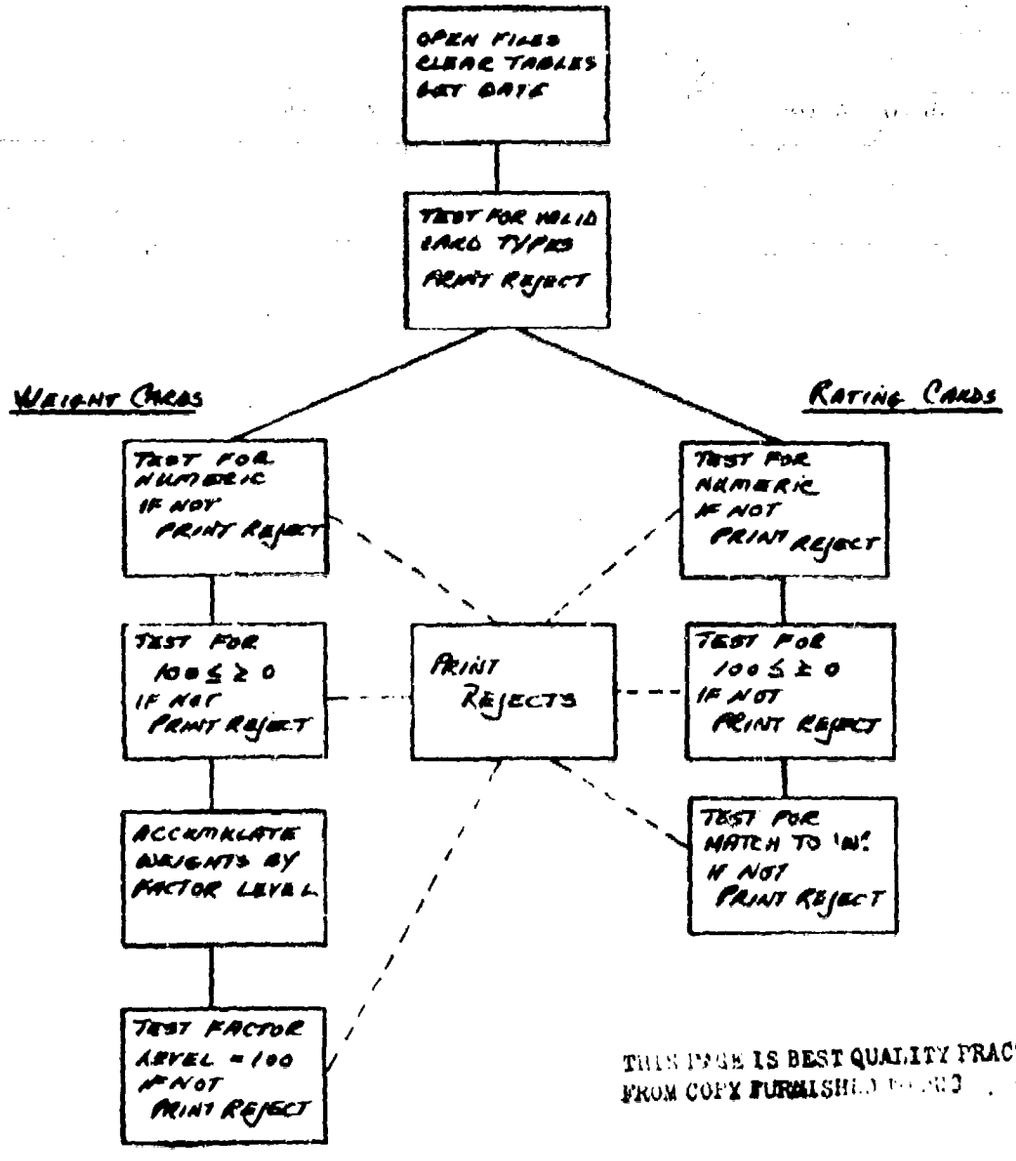
OVERALL PROGRAM FLOWCHART



Edit Module

As described on the preceding pages, the Edit Module performs almost all of the editing required on the input. The following flowcharts illustrate processing on a subroutine (overall) and detailed level.

EDIT SUBROUTINE FLOWCHART



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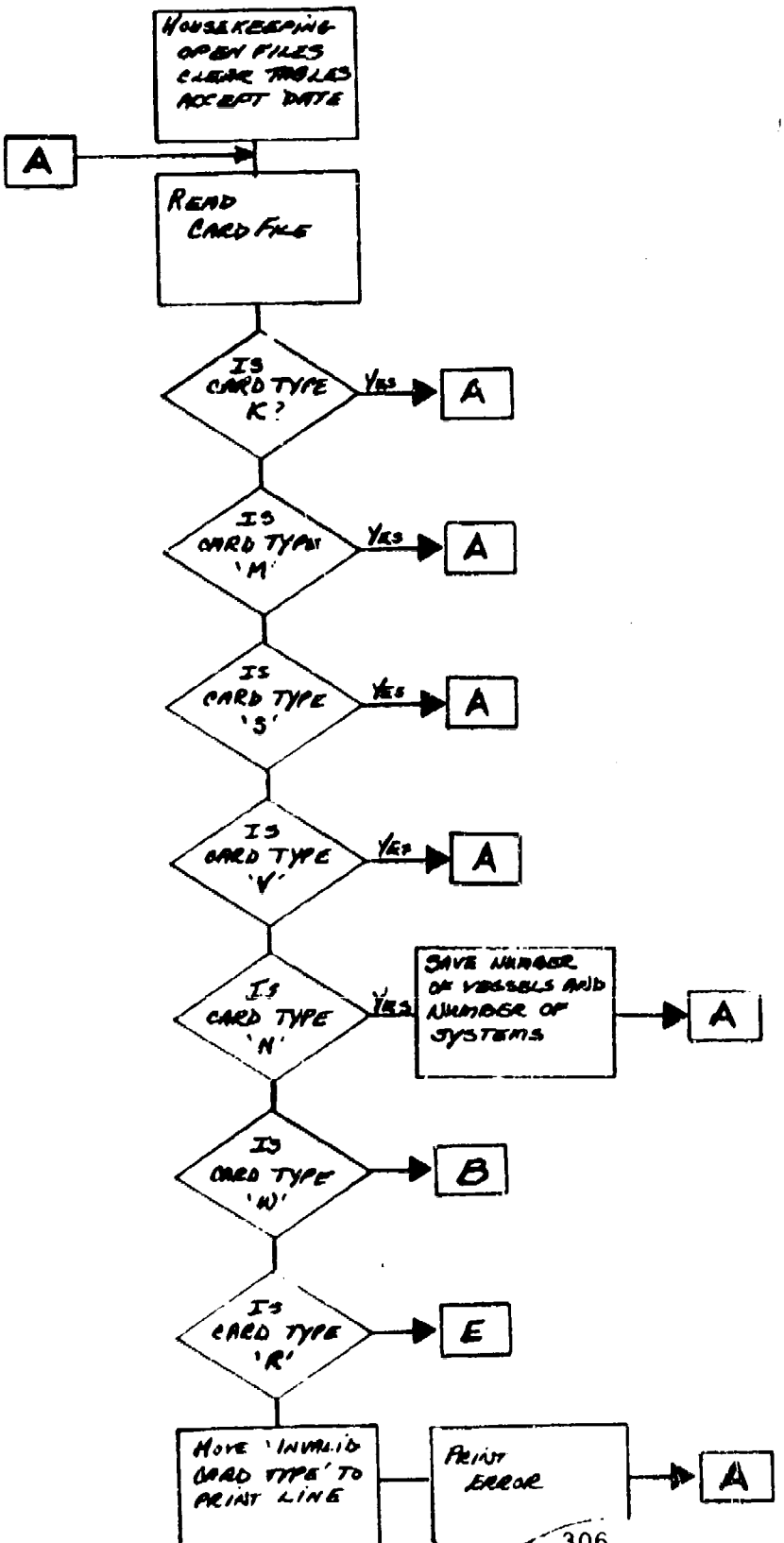
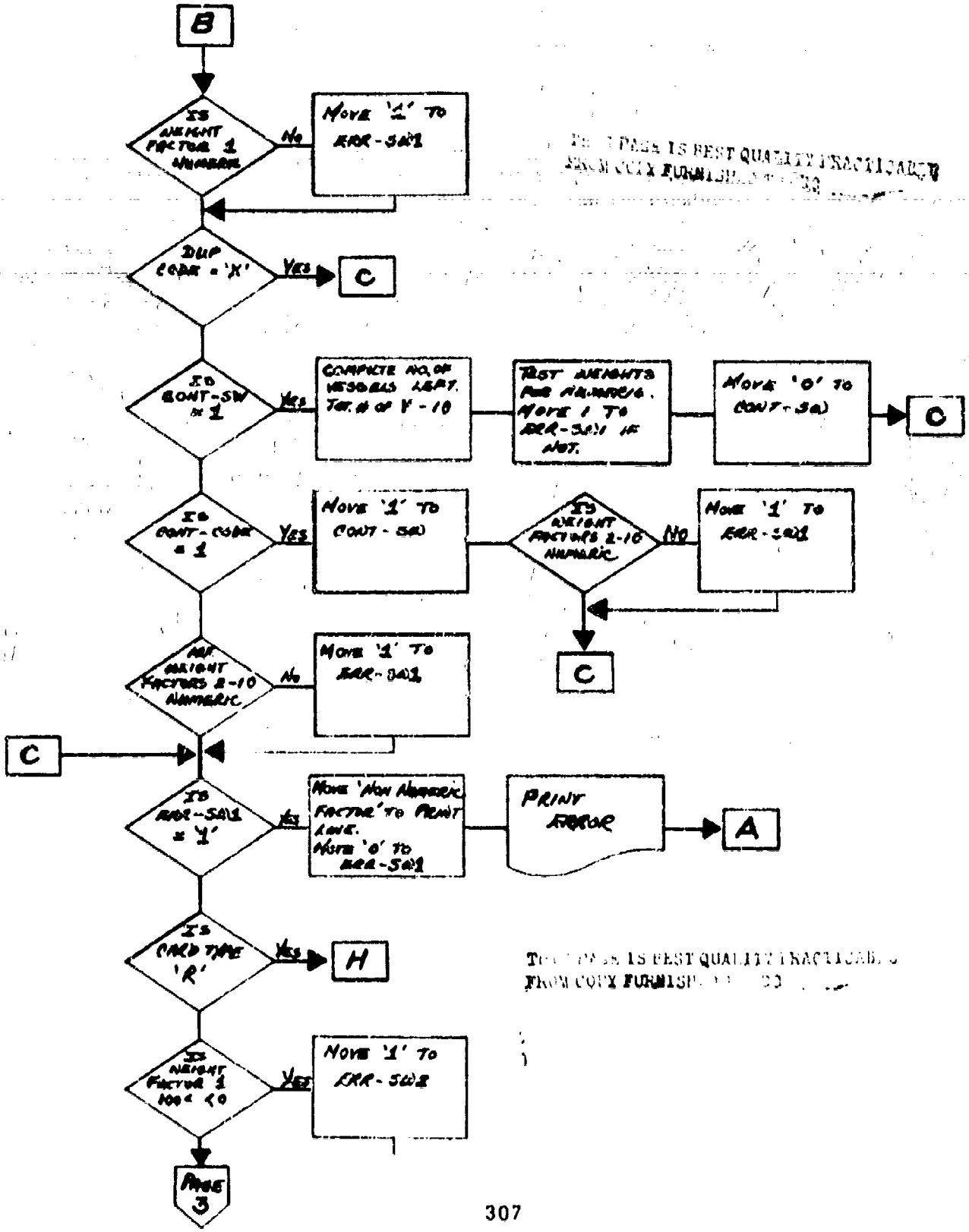
DETAILED EDIT MODULE FLOWCHART (Sheet 1 of 7)



DETAILED EDIT MODULE FLOWCHART (Sheet 2 of 7)



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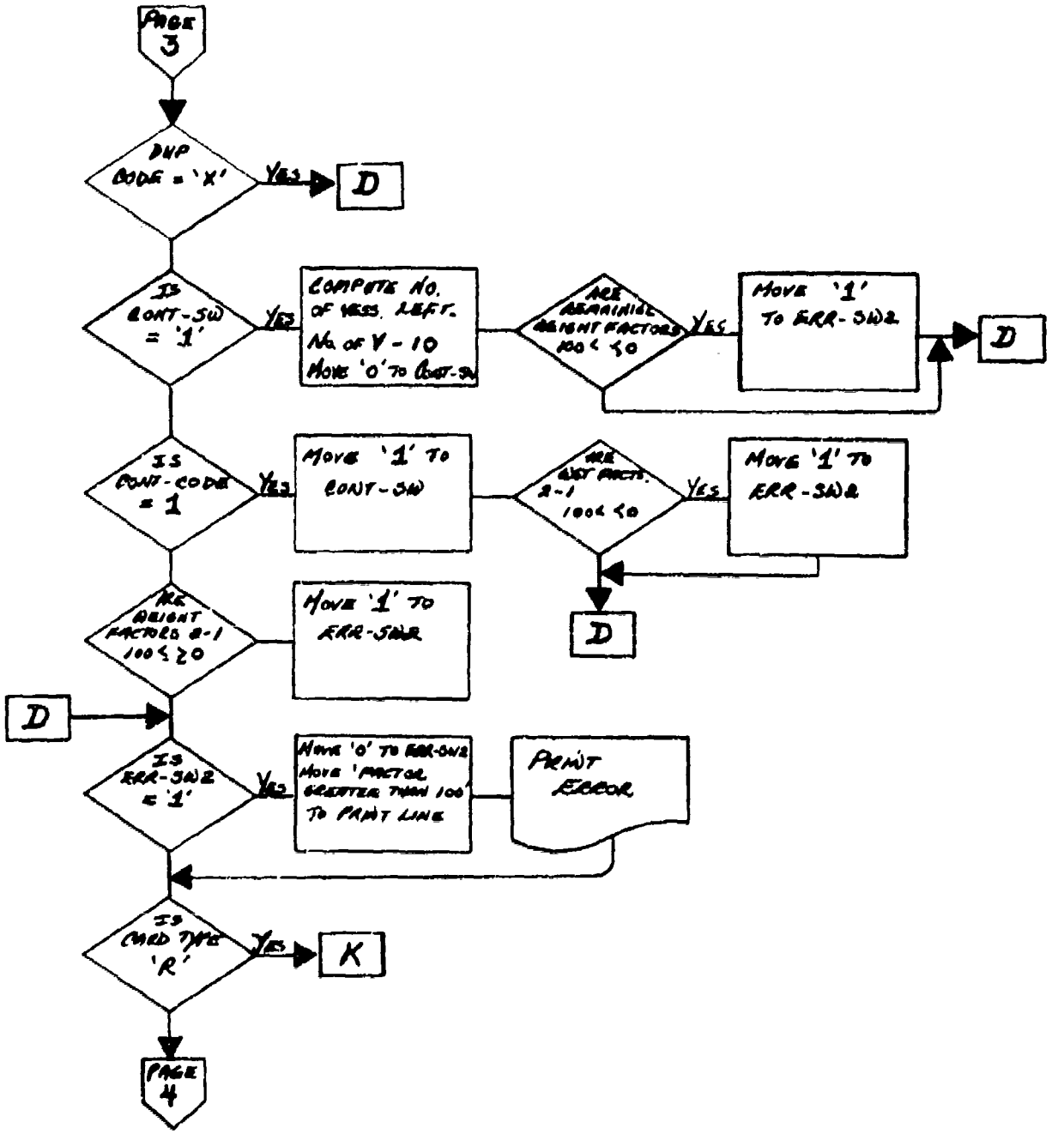
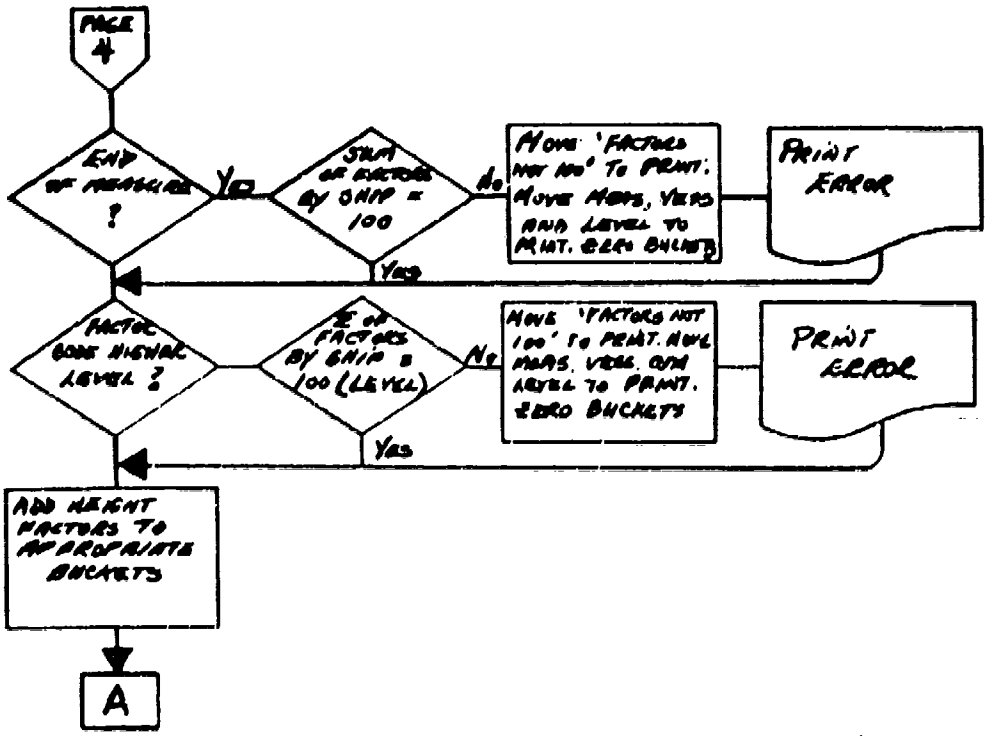
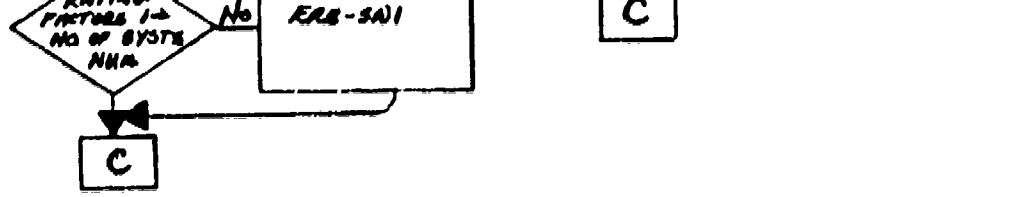
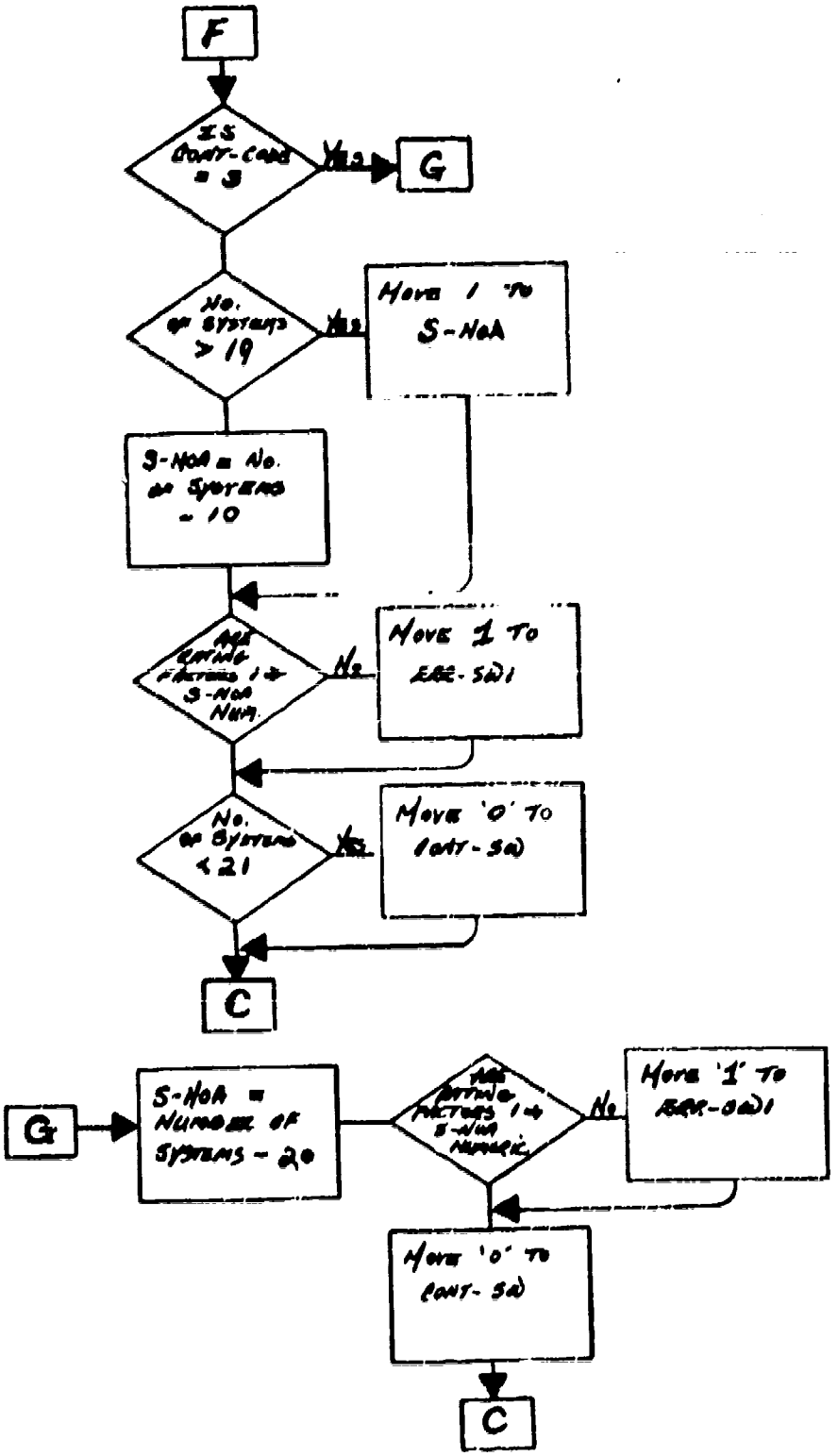
DETAILED EDIT MODULE FLOWCHART (Sheet 3 of 7)



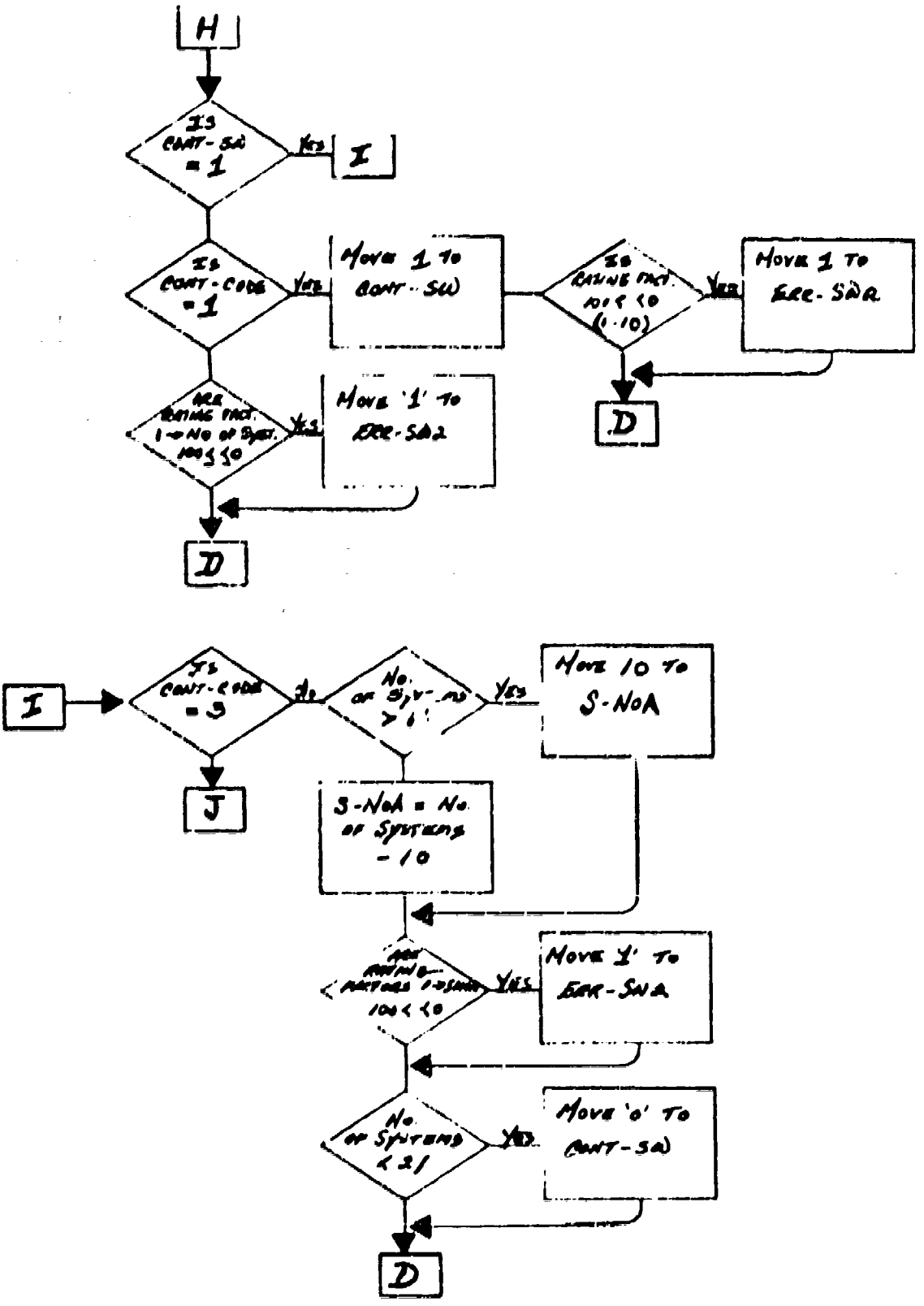

PAGE 4
END OF PARAGRAPH ?
Yes
SUM OF FACTORS BY CHIP = 100
No
MOVE 'FACTORS NOT 100' TO PRINT. MOVE MEAS, VERS AND LEVEL TO PRINT. ERR BUCKETS
PRINT ERROR
Yes
FACTOR CODE HIGHER LEVEL ?
Σ OF FACTORS BY CHIP = 100 (LEVEL)
No
MOVE 'FACTORS NOT 100' TO PRINT. MOVE MEAS. VERS. OPM LEVEL TO PRINT. ERRO BUCKETS
PRINT ERROR
Yes
ADD WEIGHT FACTORS TO APPROPRIATE BUCKETS
A


E
IS CONT-SW = 1
Yes
F
IS CONT-CODE = 1
Yes
MOVE 1 TO CONT-SW
IS RATING FACTOR 1-10 NUMERIC
No
MOVE 1 TO ERR-SW1
C
ARE RATING-FACTORS 1→ NO OF SYSTS NUM
No
MOVE 1 TO ERR-SW1
C

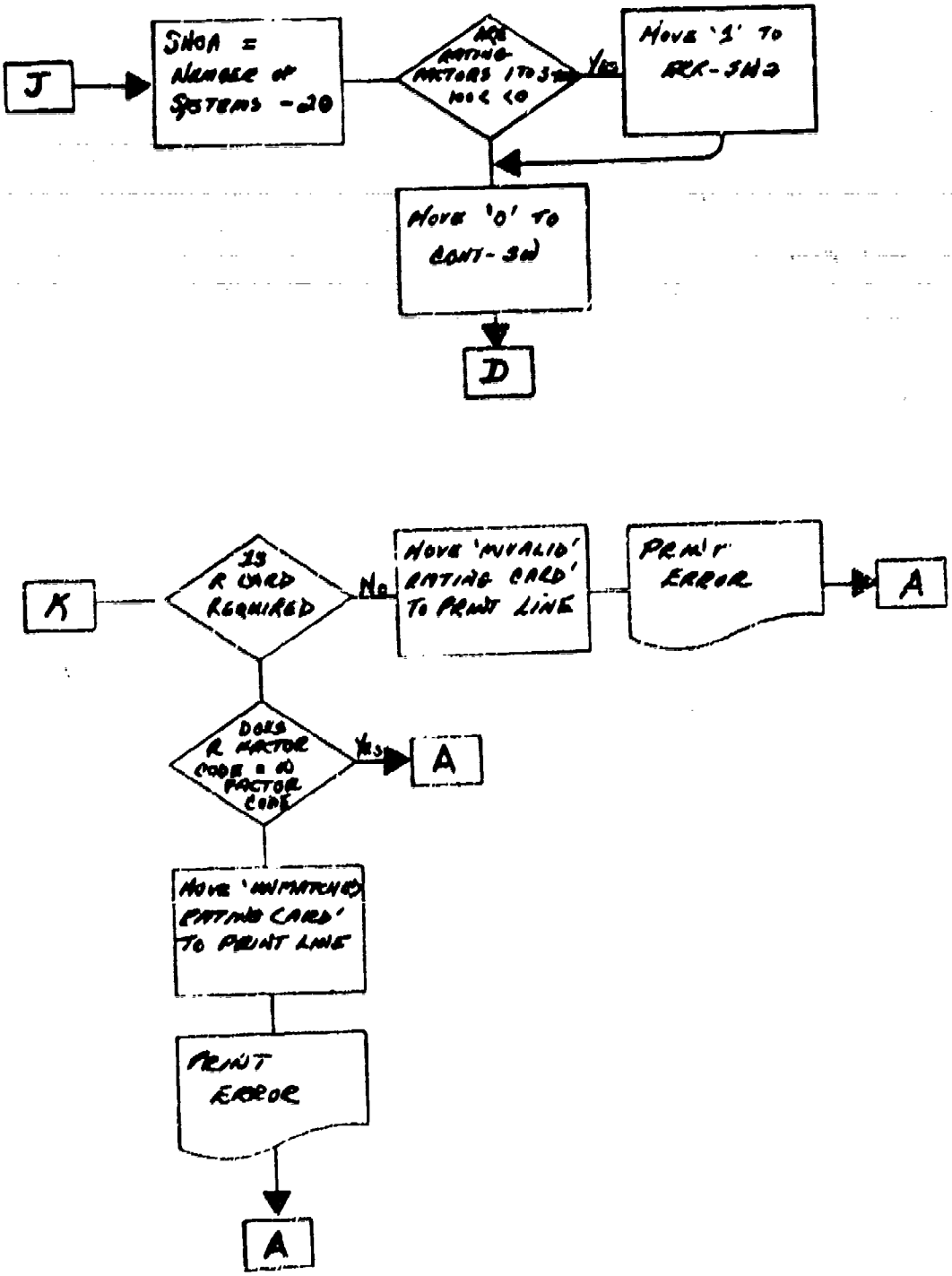
DETAILED EDIT MODULE FLOWCHART (Sheet 5 of 7)



DETAILED EDIT MODULE FLOWCHART (Sheet 6 of 7)



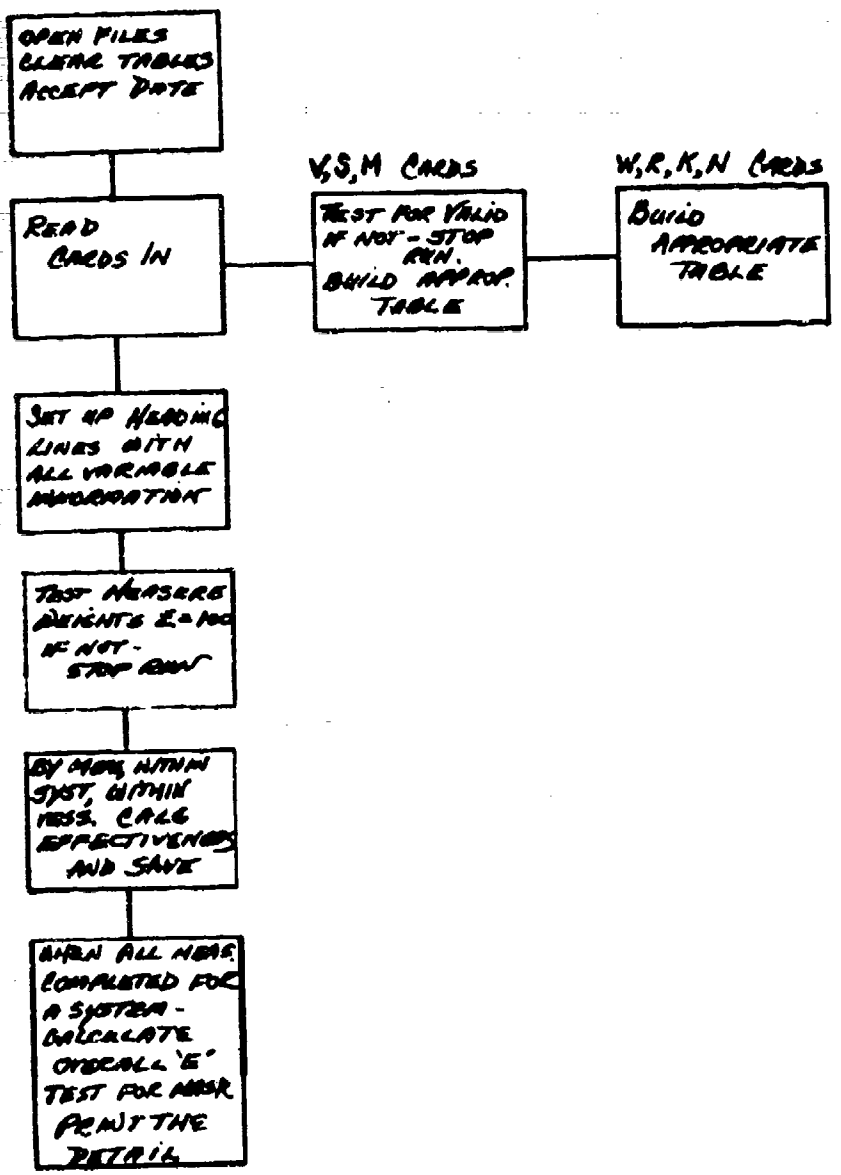
DETAILED EDIT MODULE FLOWCHART (Sheet 7 of 7)



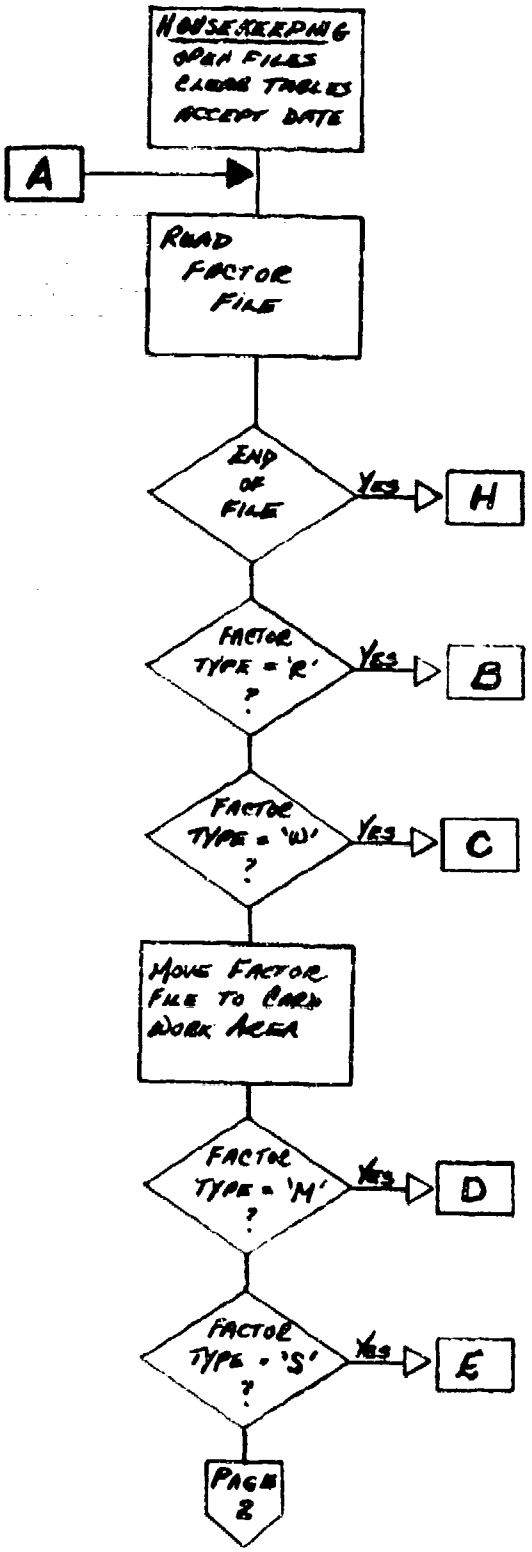
Calculation Module

As described, the primary function of this module is to calculate the overall effectiveness of each system/vessel combination. The following flowcharts illustrate processing on a subroutine (overall) and detailed level.

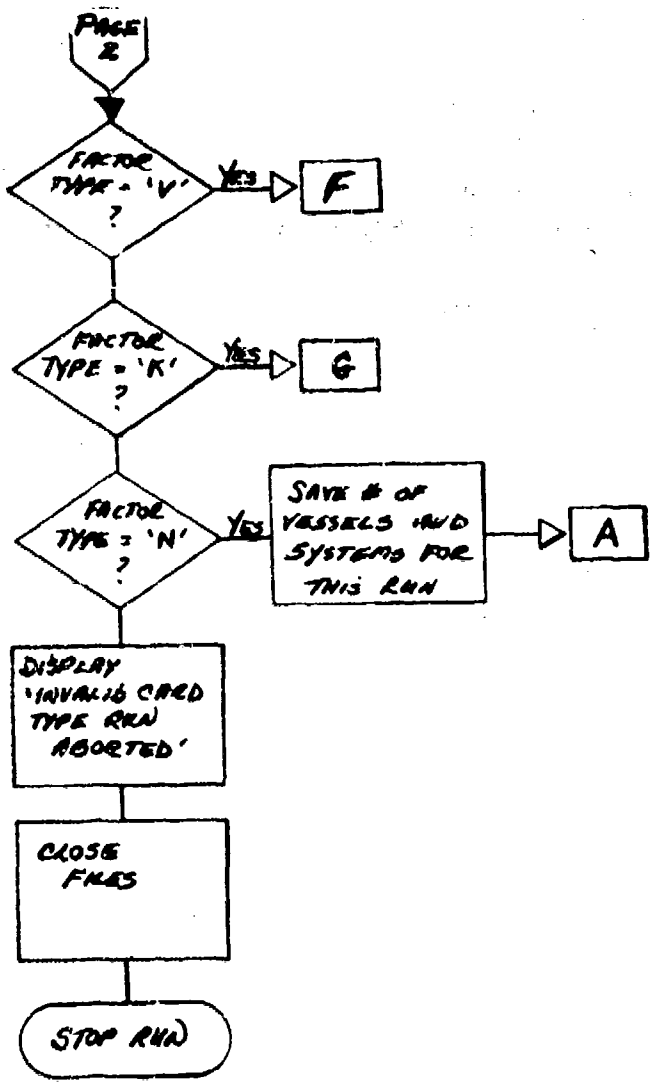
CALCULATION SUBROUTINE FLOWCHART

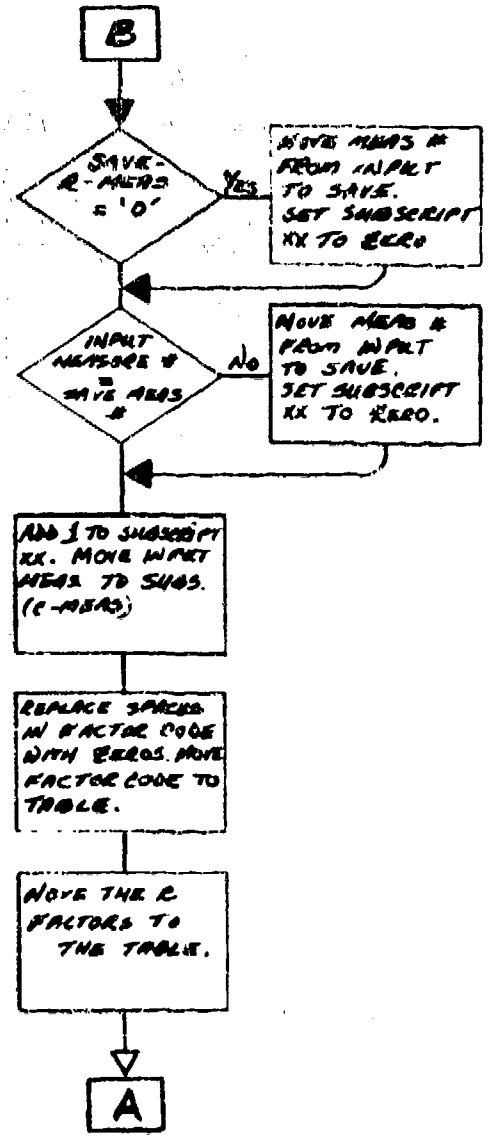


DETAILED CALCULATION MODULE FLOWCHART (Sheet 1 of 12)

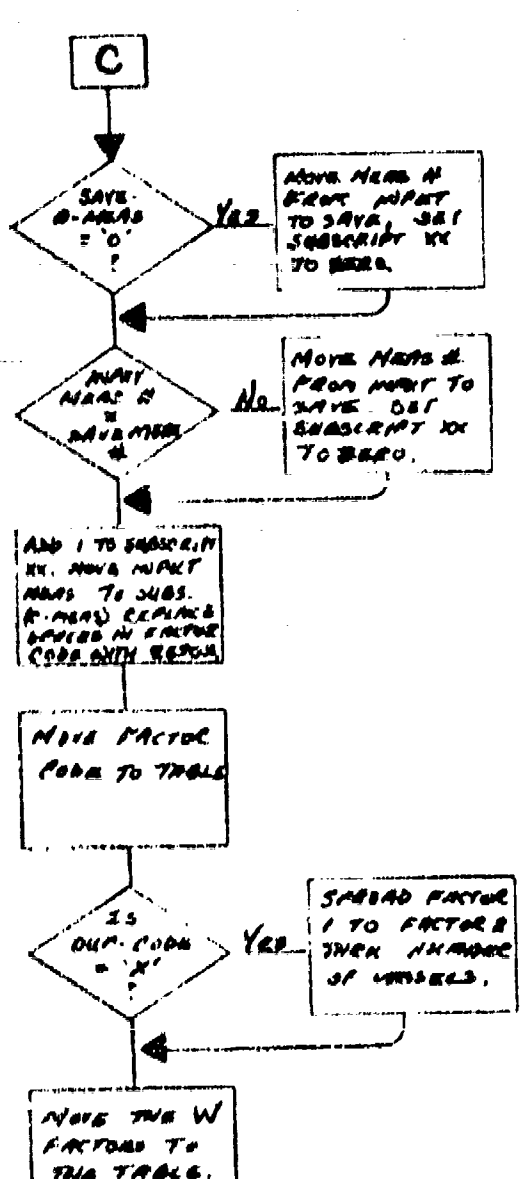


DETAILED CALCULATION MODULE FLOWCHART (Sheet 2 of 12)



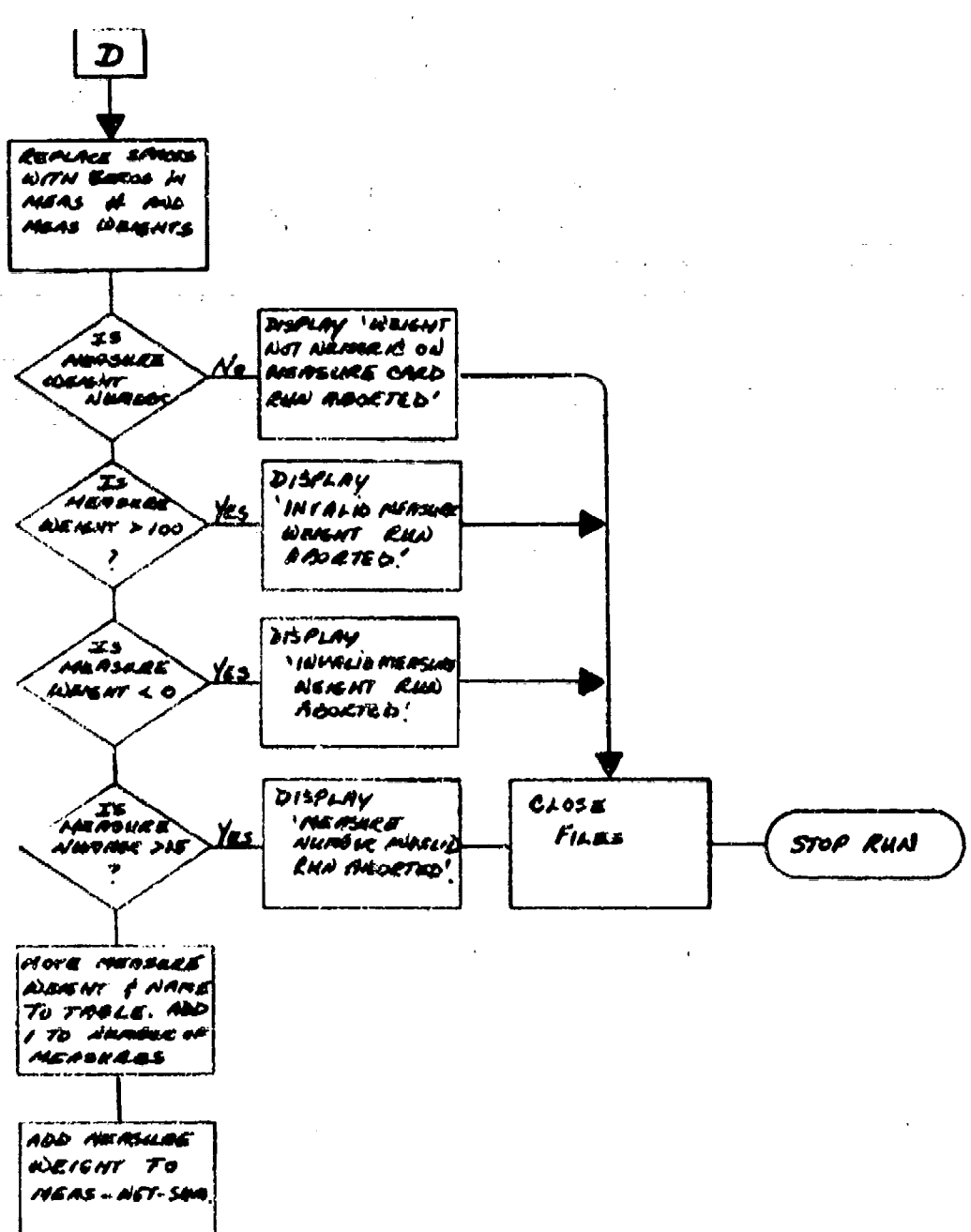


(BUILD RATING TABLE SUBROUTINE)

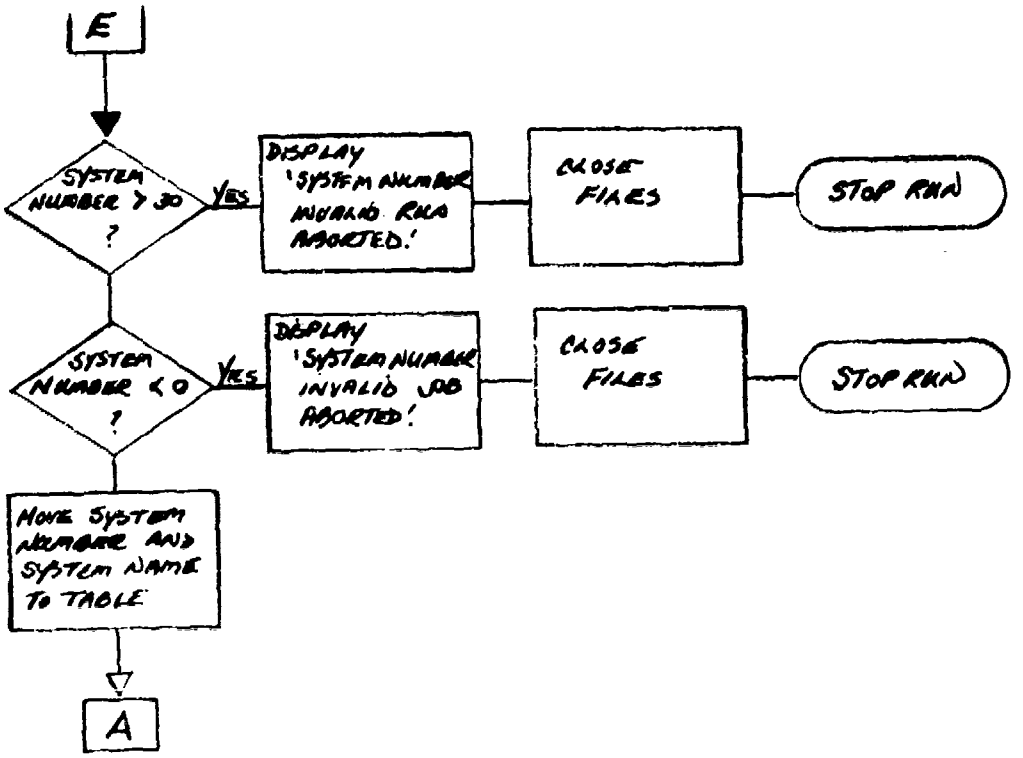


(BUILD WEIGHT TABLE SUBROUTINE)

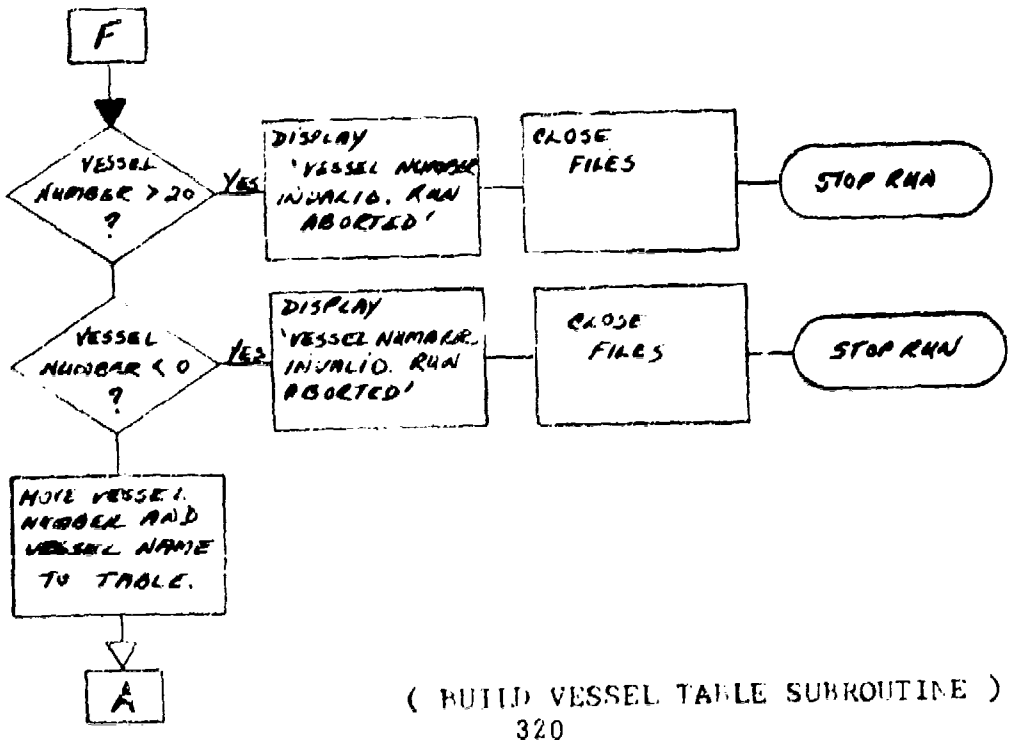
DETAILED CALCULATION MODULE FLOWCHART (Sheet 5 of 12)



(BUILD MEASURE TABLE SUBROUTINE)

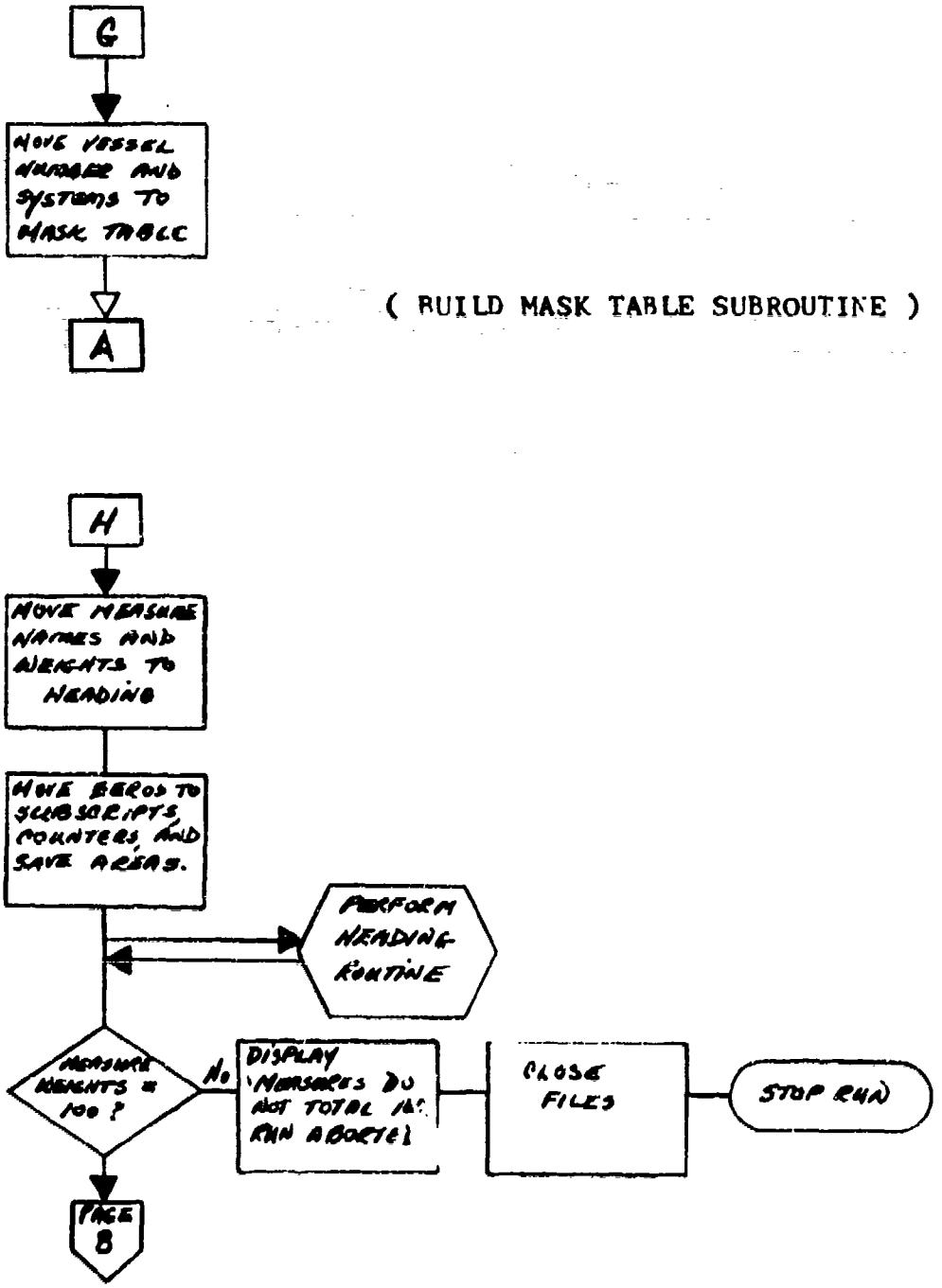


(BUILD SYSTEM TABLE SUBROUTINE)

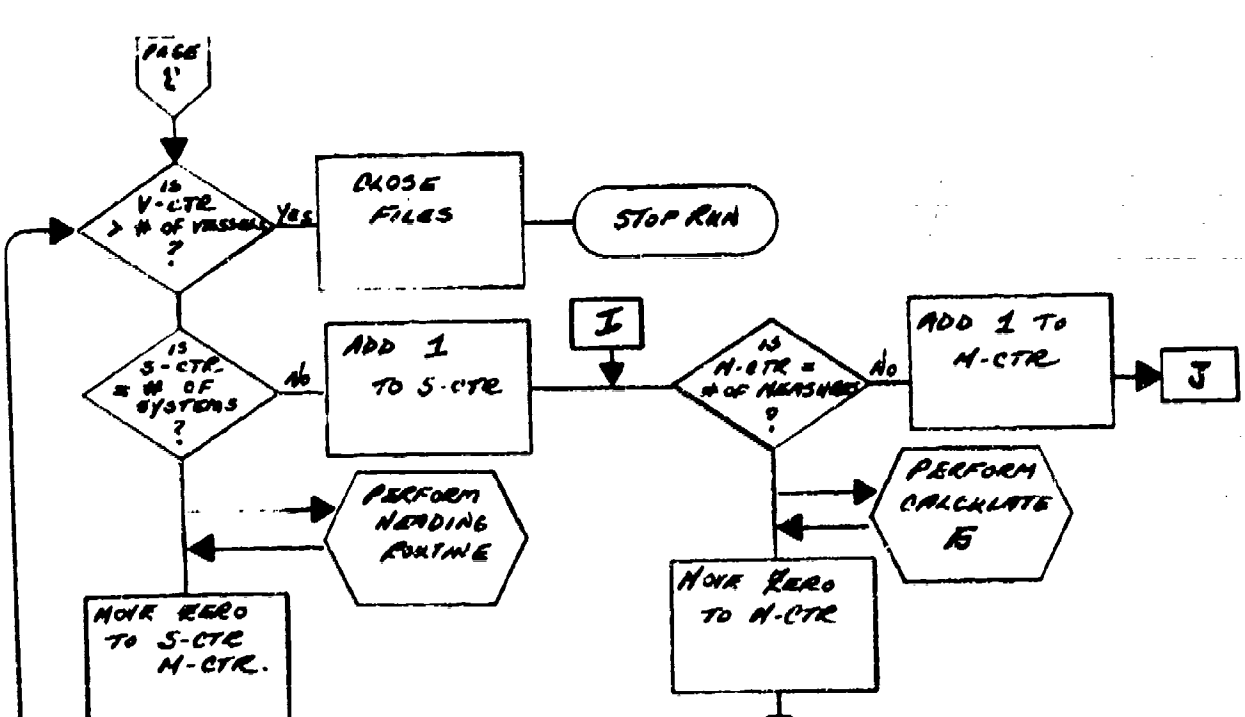


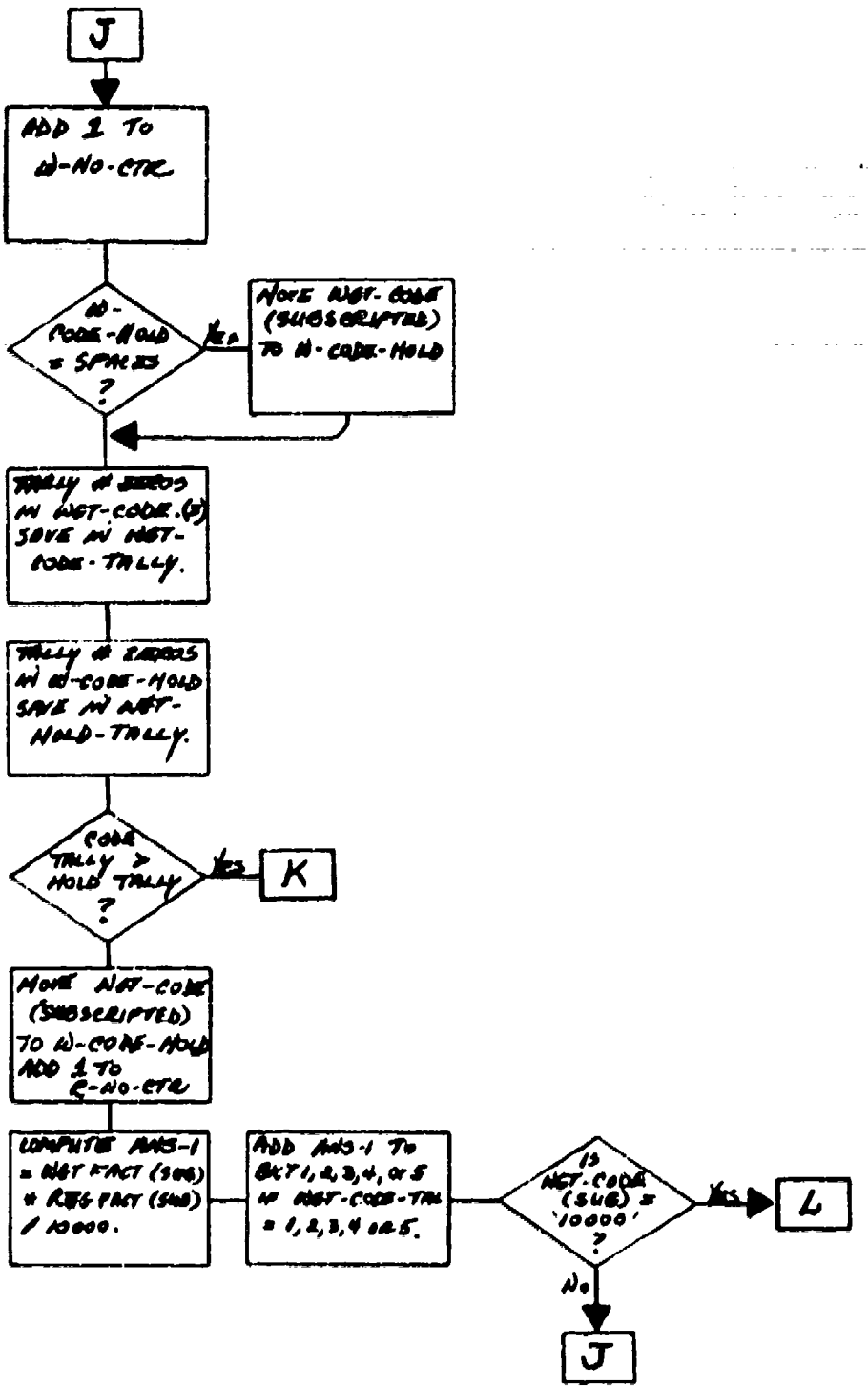
(BUILD VESSEL TABLE SUBROUTINE)

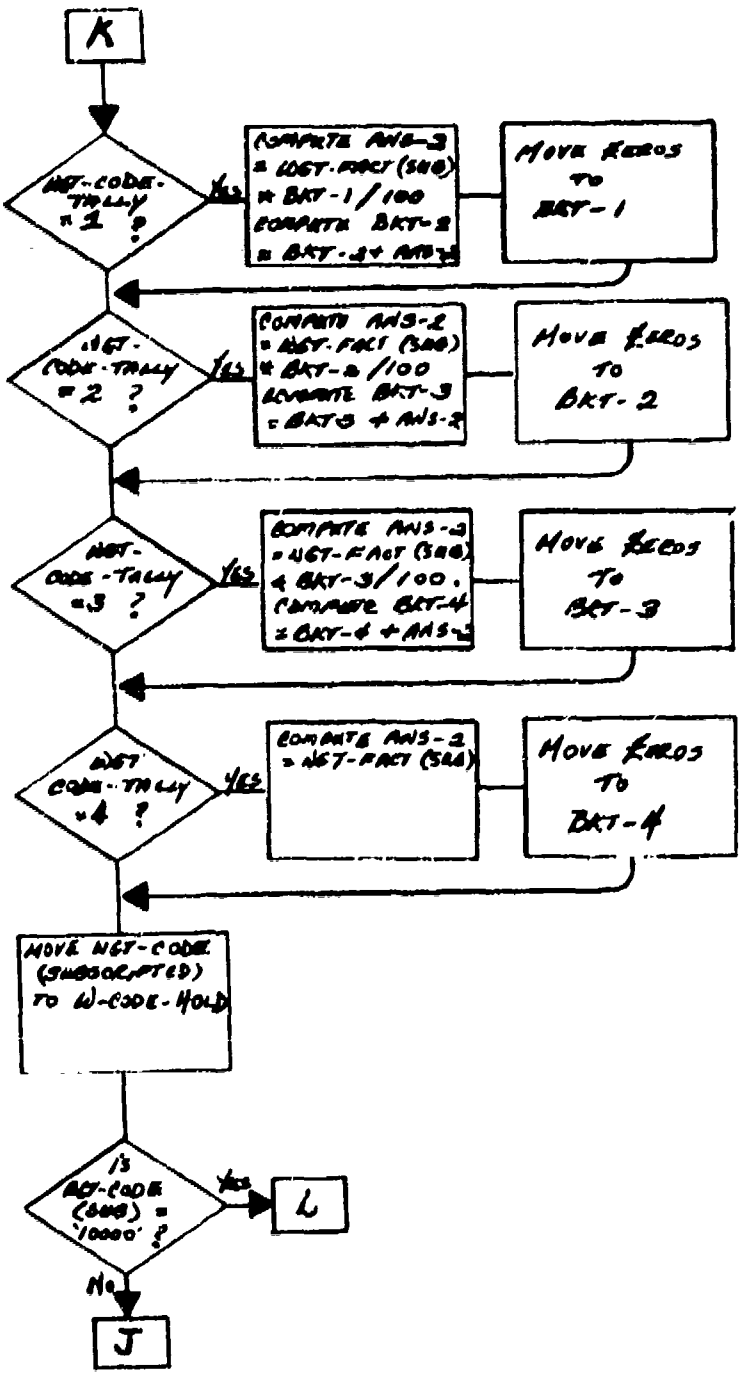
DETAILED CALCULATION MODULE FLOWCHART (Sheet 7 of 12)

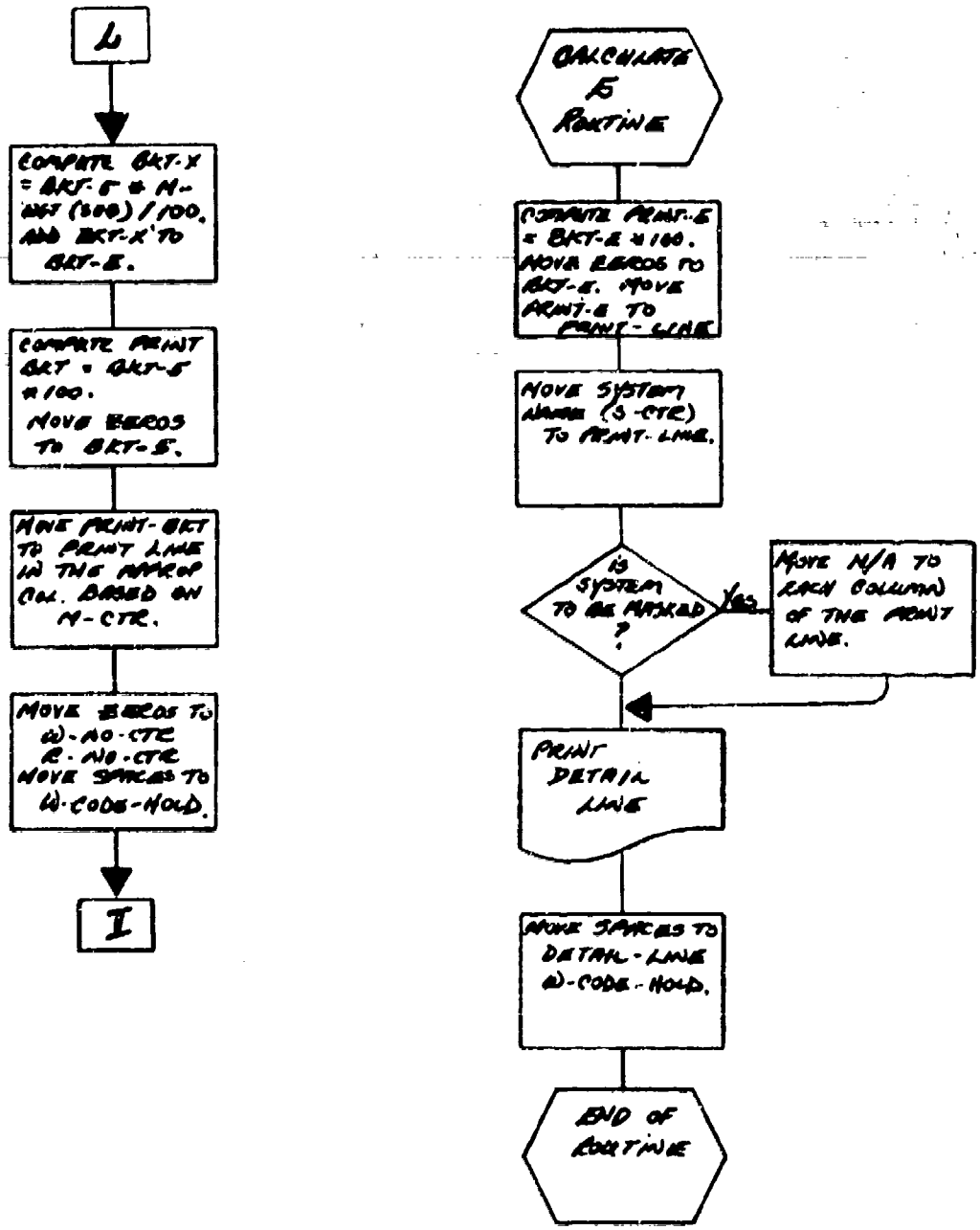


DETAILED CALCULATION MODULE FLOWCHART (Sheet 8 of 12)

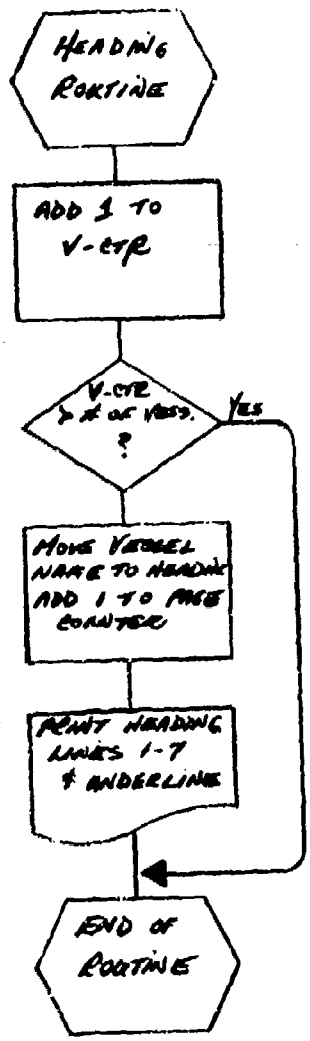



J
ADD 1 TO W-NO-CTR
W-CODE-HOLD = SPACES ?
No
MOVE NXT-CODE (SUBSCRIPTED) TO W-CODE-HOLD
TALLY # ZEROS IN NXT-CODE. (S) SAVE IN NXT-CODE-TALLY.
TALLY # ZEROS IN W-CODE-HOLD SAVE IN NXT-HOLD-TALLY.
CODE TALLY > HOLD TALLY ?
Yes
K
MOVE NXT-CODE (SUBSCRIPTED) TO W-CODE-HOLD ADD 1 TO C-NO-CTR
COMPUTE ANS-1 = NXT FACT (SUB) * REG FACT (SUB) / 10000.
ADD ANS-1 TO EXP 1, 2, 3, 4, OR 5 W NXT-CODE-TAL = 1, 2, 3, 4 OR 5.
IS NXT-CODE (SUB) = '10000' ?
Yes
L
No
J


K
NGT-CODE-TALLY = 1 ?
Yes
COMPUTE ANS-3 = NGT-FACT (SUB) * BKT-1 / 100
COMPUTE BKT-2 = BKT-4 + ANS-3
MOVE ZEROS TO BKT-1
NGT-CODE-TALLY = 2 ?
Yes
COMPUTE ANS-2 = NGT-FACT (SUB) * BKT-2 / 100
COMPUTE BKT-3 = BKT-3 + ANS-2
MOVE ZEROS TO BKT-2
NGT-CODE-TALLY = 3 ?
Yes
COMPUTE ANS-3 = NGT-FACT (SUB) * BKT-3 / 100.
COMPUTE BKT-4 = BKT-4 + ANS-3
MOVE ZEROS TO BKT-3
NGT-CODE-TALLY = 4 ?
Yes
COMPUTE ANS-2 = NGT-FACT (SUB)
MOVE ZEROS TO BKT-4
MOVE NGT-CODE (SUBSCRIPTED) TO W-CODE-HOLD
IS NGT-CODE (SUB) = '10000' ?
Yes
L
No
J


L
COMPUTE BKT-X = BKT-E * M-INT (500) / 100. ADD BKT-X TO BKT-E.
COMPUTE PRINT BKT = BKT-E * 100. MOVE ZEROS TO BKT-E.
MOVE PRINT-BKT TO PRINT LINE IN THE APPROP COL. BASED ON M-CTR.
MOVE ZEROS TO W-NO-CTR R-NO-CTR MOVE SPACES TO W-CODE-HOLD.
I
CALCULATE E ROUTINE
COMPUTE PRNT-E = BKT-E * 100. MOVE ZEROS TO BKT-E. MOVE PRNT-E TO PRINT-LINE
MOVE SYSTEM NAME (S-CTR) TO PRNT-LINE.
IS SYSTEM TO BE MASKED ?
Yes
MOVE N/A TO EACH COLUMN OF THE PRINT LINE.
PRINT DETAIL LINE
MOVE SPACES TO DETAIL-LINE W-CODE-HOLD.
END OF ROUTINE

DETAILED CALCULATION MODULE FLOWCHART (Sheet 12 of 12)



PROGRAM LISTINGS

Following are the complete listings of both the edit program module (WM1) and the calculation program module (WM2).

Edit Module (WM1) Listing (Card Images)


```
      IDENTIFICATION DIVISION.
      PROGRAM-ID. 'WM1'.
      REMARKS. COAST GUARD WASTE MANAGEMENT.
               PROGRAM EDITS WEIGHT AND RATING CARDS.
               CHECKS FOR VALIDITY OF THE FACTORS AS WELL
               AS A MATCH OF DATA.
      ENVIRONMENT DIVISION.
      INPUT-OUTPUT SECTION.
      FILE-CONTROL.
          SELECT FACTOR-FILE  ASSIGN TO UT-S-FACTORS.
          SELECT PRINT-FILE   ASSIGN TO UT-S-PRINTER.
      DATA DIVISION.
      FILE SECTION.
      FD  FACTOR-FILE
               RECORDING MODE IS F
               LABEL RECORD IS OMITTED
               RECORD CONTAINS 80
               BLOCK CONTAINS 0 RECORDS
               DATA RECORD IS FACTOR.
      01  FACTOR          PIC X(80).
      FD  PRINT-FILE
               RECORDING MODE IS F
               LABEL RECORD IS OMITTED
               RECORD CONTAINS 133
               BLOCK CONTAINS 0 RECORDS
               DATA RECORD IS P-LINE.
      01  P-LINE          PIC X(133).
      WORKING-STORAGE SECTION.
      77  LINE-CTR        PIC 99 VALUE 51.
      77  PG-CTR          PIC 99 VALUE 0.
      77  ERR-SW1         PIC 9  VALUE 0.
      77  ERR-SW2         PIC 9  VALUE 0.
      77  MEAS-SAVE       PIC XX VALUE SPACES.
      77  CODE-SAVE       PIC X(5) VALUE SPACES.
      77  FH-TALLY        PIC 9.
      77  TBL-TALLY       PIC 9.
      77  SAVE-TALLY      PIC 9.
      77  NO-R-SW         PIC 9  VALUE ZERO.
      77  SHP-SAVE        PIC 99 VALUE ZERO.
      77  ERR-SW3         PIC 9  VALUE ZERO.
      77  S               PIC 99.
      77  L               PIC 9.
      77  V-NO            PIC 99.
      77  S-NO            PIC 99.
CCCC85 77  V-NOA           PIC 99 VALUE ZERO.
      77  S-NOA           PIC 99 VALUE ZERO.
      77  CONT-SW         PIC 99 VALUE ZERO.
      77  YY              PIC S9(4).
      77  XX              PIC S9(4).
      01  FACTOR-HOLD.
          03  FH-MEAS     PIC XX.
          03  FH-MEAS-N REDEFINES FH-MEAS PIC 99.
          03  FH-TYPE     PIC X.
          03  FH-CODE     PIC X(5)
          03  FH-CODE-N REDEFINES FH-CODE PIC 9(5).
000112    03  FH-NAME     PIC X(29).
          03  FH-NUM REDEFINES FH-NAME.
              05  NO-OF-VESS  PIC 99.
              05  FILLER      PIC X.
              05  NO-OF-SYST  PIC 99.
```

```
000122          05  FILLER          PIC X(24).
            03  FH-SHIP      PIC XX.
            03  FH-SHIP-N REDEFINES FH-SHIP PIC 99.
            03  DUP-CODE     PIC X.
000130      03  FH-FACTORS OCCURS 10 TIMES.
000122          05  FH-F1    PIC XXX.
000124          05  FH-F1-A REDEFINES FH-F1 PIC 999.
000126          05  CONT-CODE    PIC X.
        01  HEAD-1.
000168      03  FILLER          PIC X(10) VALUE SPACES.
000200      03  H-DATE          PIC X(8).
            03  FILLER          PIC XX VALUE SPACES.
            03  FILLER          PIC X(25) VALUE 'COAST GUARD WASTE MANAGEM'.
            03  FILLER          PIC X(25) VALUE 'ENT WEIGHT AND RATING CAR'.
            03  FILLER          PIC X(21) VALUE 'D REJECTS        PAGE '.
            03  H-PAGE          PIC ZZ.
            03  FILLER          PIC X(40) VALUE SPACES.
        01  HEAD-2.
            03  FILLER          PIC X(21) VALUE '          REJECT CARD'.
            03  FILLER          PIC X(74) VALUE SPACES.
            03  FILLER          PIC X(14) VALUE 'REJECT MESSAGE'.
            03  FILLER          PIC X(24) VALUE SPACES.
        01  DET-LINE.
            03  FILLER          PIC X(10).
            03  DET-CC          PIC X(85).
            03  DET-MSG         PIC X(38).
        01  TABLE-A.
000234      03  TBL-SHUP OCCURS 20 TIMES.
                05  TBL-LVL OCCURS 5 TIMES  PIC 999.
        01  NOT-100.
            03  FILLER          PIC X(18) VALUE '          MEASURE '.
            03  M-100           PIC XX  VALUE SPACES.
            03  FILLER          PIC X(7)  VALUE '  SHIP '.
            03  S-100           PIC XX  VALUE SPACES.
            03  FILLER          PIC X(8)  VALUE '  LEVEL '.
000192      03  L-100           PIC X(5)  VALUE SPACES.
000194      03  FILLER          PIC X(53) VALUE SPACES.
            03  FILLER          PIC X(15) VALUE 'FACTORS NOT 100'.
            03  FILLER          PIC X(23) VALUE SPACES.
        PROCEDURE DIVISION.
            ACCEPT H-DATE.
            MOVE SPACES TO DET-LINE.
            OPEN INPUT FACTOR-FILE.
            OPEN OUTPUT PRINT-FILE.
            PERFORM CLEAR-TABLE VARYING S FROM 1 BY 1 UNTIL S GREATER
000270          THAN 20 AFTER L FROM 1 BY 1 UNTIL L GREATER THAN 5.
        READ-FACTOR.
            READ FACTOR-FILE INTO FACTOR-HOLD AT END GO TO EOJ.
000217      IF FH-TYPE = 'K' GO TO READ-FACTOR.
000276      IF FH-TYPE = 'M' GO TO READ-FACTOR.
000278      IF FH-TYPE = 'S' GO TO READ-FACTOR.
000280      IF FH-TYPE = 'V' GO TO READ-FACTOR.
000282      IF FH-TYPE = 'N'
000283          MOVE NO-OF-VESS TO V-NO
                MOVE NO-OF-SYST TO S-NO
                GO TO READ-FACTOR.
            EXAMINE FH-CODE REPLACING ALL SPACES BY ZEROS.
000286      IF FH-TYPE = 'W' GO TO SET-ERR-SW-1W.
000288      IF FH-TYPE = 'R' GO TO SET-ERR-SW-1R.
000290      MOVE 'INVALID CARD TYPE' TO DET-MSG.
```

```
000292      PERFORM PRINT-RTN.
000294      GO TO READ-FACTOR.
000296 SET-ERR-SW-1W.
000298      IF FW-F1-N (1) NOT NUMERIC MOVE 1 TO ERR-SW1.
000300      IF DUP-CODE = 'X' GO TO TEST-ERR-SW-1W.
000302      IF CONT-SW = '1' GO TO SET-1W-CONT.
000304      IF CONT-CODE (10) = '1'
000306          MOVE 1 TO CONT-SW
000308          PERFORM TEST-W-NUM VARYING YY FROM 2 BY 1 UNTIL
000310              YY GREATER THAN 10
000312          GO TO TEST-ERR-SW-1W.
000314      PERFORM TEST-W-NUM VARYING YY FROM 2 BY 1 UNTIL
000316          YY GREATER THAN V-NO.
000318      GO TO TEST-ERR-SW-1W.
000320 TEST-W-NUM.
000322      IF FW-F1-N (YY) NOT NUMERIC MOVE 1 TO ERR-SW1.
000324 SET-1W-CONT.
000326      COMPUTE V-NOA = V-NO - 10.
000328      PERFORM TEST-W-NUM VARYING YY FROM 1 BY 1 UNTIL
000330          YY GREATER THAN V-NOA.
000332      MOVE ZERO TO CONT-SW.
000344 TEST-ERR-SW-1W.
            IF ERR-SW1 = 1
                MOVE 'NON NUMERIC FACTOR' TO GET-MSG
                PERFORM PRINT-RTN
000290          MOVE ZERO TO ERR-SW1
                GO TO READ-FACTOR.
000291      IF F1-TYPE = 'R' GO TO SET-R-100.
000354      IF FW-F1-N (1) GREATER THAN 100 MOVE 1 TO ERR-SW2.
000356      IF DUP-CODE = 'X' GO TO TEST-ERR-SW-2W.
000304      IF CONT-CODE (10) = '1'
000362          MOVE 1 TO CONT-SW
000364          PERFORM TEST-W-100 VARYING YY FROM 2 BY 1 UNTIL
000310              YY GREATER THAN 10
000368          GO TO TEST-ERR-SW-2W.
000313      IF CONT-SW = 1 GO TO SET-2W-CONT.
000370      PERFORM TEST-W-100 VARYING YY FROM 2 BY 1 UNTIL
000372          YY GREATER THAN V-NO.
000374      GO TO TEST-ERR-SW-2W.
000376 TEST-W-100.
000378      IF FW-F1-N (YY) GREATER THAN 100 MOVE 1 TO ERR-SW2.
000380 SET-2W-CONT.
000326      COMPUTE V-NOA = V-NO - 10
            PERFORM TEST-W-100 VARYING YY FROM 1 BY 1 UNTIL
                YY GREATER THAN V-NOA.
            MOVE ZERO TO CONT-SW.
000382 TEST-ERR-SW-2W.
            IF ERR-SW2 = 1
                MOVE 'FACTOR GREATER THAN 100' TO GET-MSG
                PERFORM PRINT-RTN
                MOVE ZERO TO ERR-SW2.
000331      IF FW-TYPE = 'N' GO TO RTG-RTN.
000342      GO TO NGT-RTN.
        PRINT-RTN.
            IF LINE-CTR GREATER THAN 50
                ADD 1 TO PG-CTR
                MOVE PG-CTR TO P-PAGE
                WRITE P-LINE FROM HEAD-1 AFTER POSITIONING 0 LINES
                WRITE P-LINE FROM HEAD-2 AFTER POSITIONING 3 LINES
                MOVE 7 TO LINE-CTR.
```

```
                MOVE FACTOR-HOLD TO DET-CD.
                WRITE P-LINE FROM DET-LINE AFTER POSITIONING 2 LINES.
                ADD 2 TO LINE-CTR.
                MOVE SPACES TO DET-LINE.
            BGT-RTN.
                IF MEAS-SAVE = SPACES
                    MOVE FH-MEAS TO MEAS-SAVE.
                IF FH-MEAS NOT EQUAL TO MEAS-SAVE
    000472          PERFORM TEST-LEVEL-1
                    MOVE FH-MEAS TO MEAS-SAVE.
                IF CODE-SAVE = SPACES
                    MOVE FH-CODE TO CODE-SAVE.
                EXAMINE FH-CODE TALLYING ALL ZEROS.
                MOVE TALLY TO FH-TALLY.
                EXAMINE CODE-SAVE TALLYING ALL ZEROS.
                MOVE TALLY TO SAVE-TALLY.
                IF SAVE-TALLY LESS THAN FH-TALLY
                    GO TO TEST-LEVELS.
                MOVE ZERO TO NO-R-SW
            SAVE-NEW-CODE.
                MOVE FH-CODE TO CODE-SAVE.
                MOVE ZERO TO TBL-TALLY.
                ADD FH-TALLY TO TBL-TALLY.
                ADD 1 TO TBL-TALLY.
    000504      IF DUP-CODE = '2' PERFORM SPREAD-DUP-N VARYING YY
    000506          FROM 1 BY 1 UNTIL YY GREATER THAN V-NO
    000508          GO TO READ-FACTOR.
    000410      IF CONT-CODE (10) = '2'
    000418          COMPUTE V-NOA = V-NO - 10
    000512          PERFORM SPREAD-N2 VARYING YY FROM 1 BY 1 UNTIL
    000514              YY GREATER THAN V-NOA
    000516          GO TO READ-FACTOR.
    000426      IF CONT-CODE (10) = '1'
    000520          PERFORM SPREAD-N VARYING YY FROM 1 BY 1 UNTIL
    000430              YY GREATER THAN 10
    000524          GO TO READ-FACTOR.
    000524      PERFORM SPREAD-N VARYING YY FROM 1 BY 1 UNTIL
    000528          YY GREATER THAN V-NO.
    000530      GO TO READ-FACTOR.
    000531  SPREAD-DUP-N.
                ADD FH-FI-N (1) TO TBL-LVL (YY,TBL-TALLY).
            SPREAD-N2.
    000440      COMPUTE XX = YY + 10.
                ADD FH-FI-N (YY) TO TBL-LVL (XX,TBL-TALLY).
            SPREAD-N.
                ADD FH-FI-N (YY) TO TBL-LVL (YY,TBL-TALLY).
    000445  SET-ERR-SW-1N.
                IF CONT-SW = 1 GO TO SET-IN-CONT.
    000450      IF CONT-CODE (10) = '1'
                    MOVE 1 TO CONT-SW
                    PERFORM TEST-R-NUM VARYING YY FROM 1 BY 1 UNTIL
    000454              YY GREATER THAN 10
    000460          GO TO TEST-ERR-SW-1N.
                PERFORM TEST-R-NUM VARYING YY FROM 1 BY 1 UNTIL
                    YY GREATER THAN V-NO.
                GO TO TEST-ERR-SW-1N.
            TEST-R-NUM.
                IF FH-FI-N (YY) NOT NUMERIC MOVE 1 TO ERR-SW1.
            SET-IN-CONT.
    000480      IF CONT-CODE (10) = '2'
```

```
                GO TO SET-1A-CONTA.
000484      IF S-NO GREATER THAN 19 MOVE 1C TO S-NOA
                ELSE
000488          COMPUTE S-NOA = S-NO - 1C
            PERFORM TEST-A-NUM VARYING YY FROM 1 BY 1 UNTIL
                YY GREATER THAN S-NOA.
000494      IF S-NO LESS THAN 21 AND
000496          IF *RR-SW1 = 1 MOVE ZERO TO CONT-SW.
            GO TO TEST-ERR-SW-1A.
        SET-1A-CONTA.
000502      COMPUTE S-NOA = S-NO - 20
            PERFORM TEST-A-NUM VARYING YY FROM 1 BY 1 UNTIL
                YY GREATER THAN S-NOA.
000508      IF ERR-SW1 = 1 MOVE ZERO TO CONT-SW.
000510      GO TO TEST-ERR-SW-1A.
        SET-A-100.
000516      IF CONT-CODE (103) = '1'
000914          MOVE 1 TO CONT-SW
                PERFORM TEST-A-1CO VARYING YY FROM 1 BY 1 UNTIL
000922              YY GREATER THAN 10
000924          GO TO TEST-ERR-SW-2A.
000926      IF CONT-SW = 1 GO TO SET-2A-CONT.
            PERFORM TEST-A-100 VARYING YY FROM 1 BY 1 UNTIL
                YY GREATER THAN S-NO.
            GO TO TEST-ERR-SW-2A.
        TEST-A-1CO.
            IF FA-FJ-N (YY) GREATER THAN 1CO MOVE 1 TO ERR-SW2.
        SET-2A-CONT.
000938      IF CONT-CODE (1C) = '3'
                GO TO SET-2A-CONTA.
000942      IF S-NO GREATER THAN 19 MOVE 1O TO S-NOA
                ELSE
000946          COMPUTE S-NOA = S-NO - 1C
            PERFORM TEST-A-100 VARYING YY FROM 1 BY 1 UNTIL
                YY GREATER THAN S-NOA.
000952      IF S-NO LESS THAN 21
                MOVE ZERO TO CONT-SW.
            GO TO TEST-ERR-SW-2A.
        SET-2A-CONTA.
000960      COMPUTE S-NOA = S-NO - 20
            PERFORM TEST-A-100 VARYING YY FROM 1 BY 1 UNTIL
                YY GREATER THAN S-NOA.
            MOVE ZERO TO CONT-SW.
            GO TO TEST-ERR-SW-2A.
        RTG-RTN.
            IF NO-R-SW = 1
                MOVE 'INVALID RATING CARD' TO DET-MSG
                PERFORM PRINT-RTN
                MOVE ZERO TO NO-R-SW
                GO TO READ-FACTOR.
            IF FR-CODE EQUAL CODE-SAVE GO TO READ-FACTOR.
            MOVE 'UNMATCHED RATING CARD' TO DET-MSG.
            PERFORM PRINT-RTN.
            GO TO READ-FACTOR.
        TEST-LEVEL-1.
000986      PERFORM CHECK-LVL-1-FOR-100 VARYING YY FROM 1 BY 1
000994          UNTIL YY GREATER THAN S-NO.
000998      MOVE SPACES TO CODE-SAVE.
000960  CHECK-LVL-1-FOR-100.
000962      IF TBL-LVL (YY,9) NOT = 1CC
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000564          MOVE YY TO SHP-SAVE
000566          PERFORM LEVEL-1-REJECT.
000568      MOVE ZEROS TO TBL-LVL (YY,5).
        LEVEL-1-REJECT.
            IF LINE-CTR GREATER THAN 50
                ADD 1 TO PG-CTR
                MOVE PG-CTR TO H-PAGE
                WRITE P-LINE FROM HEAD-1 AFTER POSITIONING C LINES
                WRITE P-LINE FROM HEAD-2 AFTER POSITIONING 3 LINES
                MOVE 7 TO LINE-CTR.
            MOVE MEAS-SAVE TO M-100.
            MOVE SHP-SAVE TO S-100.
            MOVE "5" TO L-100.
            IF ERR-SW3 = 1
                MOVE CODE-SAVE TO L-100 MOVE ZERO TO ERR-SW3.
            WRITE P-LINE FROM NOT-100 AFTER POSITIONING 2 LINES.
            ADD 2 TO LINE-CTR.
            MOVE SPACES TO M-100 S-100 L-100.
        TEST-LEVELS.
            ADD 1 TO SAVE-TALLY.
000746      PERFORM CHECK-FOR-100 VARYING YY FROM 1 BY 1 UNTIL
000748          YY GREATER THAN V-NO.
000750      MOVE 1 TO NO-R-SW.
000752      GO TO SAVE-W-CODE.
000754  CHECK-FOR-100.
000756      IF TBL-LVL (YY,SAVE-TALLY) NOT = 100
000758          MOVE YY TO SHP-SAVE
000760          MOVE 1 TO ERR-SW3
000762          PERFORM LEVEL-1-REJECT.
000764      MOVE ZEROS TO TBL-LVL (YY,SAVE-TALLY).
        CLEAR-TABLE.
            MOVE ZEROS TO TBL-LVL (S,L).
        EOJ.
            CLOSE FACTOR-FILE.
            CLOSE PRINT-FILE.
            STOP RUN.
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       IDENTIFICATION DIVISION.
       PROGRAM-ID. 'WM2'.
       REMARKS. COAST GUARD WASTE MANAGEMENT.
                COST EFFECTIVENESS OF WASTE WATER MANAGEMENT
                SYSTEMS FOR COAST GUARD VESSELS.
       ENVIRONMENT DIVISION.
       INPUT-OUTPUT SECTION.
       FILE-CONTROL.
           SELECT FACTOR-FILE ASSIGN TO UT-S-FACTORIN.
           SELECT PRINT-FILE  ASSIGN TO LT-S-PRINTER.
       DATA DIVISION.
       FILE SECTION.
       FD  FACTOR-FILE
                RECORDING MODE IS F
                LABEL RECORD IS OMITTED
                RECORD CONTAINS 80
                BLOCK CONTAINS 0 RECORDS
                DATA RECORD IS FACTORS.
       01  FACTORS      PIC X(80).
       FD  PRINT-FILE
                RECORDING MODE IS F
                LABEL RECORD IS OMITTED
                RECORD CONTAINS 133
                BLOCK CONTAINS 0 RECORDS
                DATA RECORD IS P-LINE.
       01  P-LINE       PIC X(133).
       WORKING-STORAGE SECTION.
       77  PG-CTR       PIC 99  VALUE ZERO.
       77  M-CTR        PIC 99  VALUE ZERO.
       77  S-CTR        PIC 99  VALUE ZERO.
       77  V-CTR        PIC 99  VALUE ZERO.
       77  SAVE-R-MEAS  PIC 99  VALUE ZERO.
       77  SAVE-W-MEAS  PIC 99  VALUE ZERO.
       77  WGT-CODE-TALLY  PIC 9.
       77  WGT-HOLD-TALLY  PIC 9.
       77  W-CODE-HOLD     PIC X(5) VALUE SPACES.
       77  MEAS-WGT-SUM    PIC 999 VALUE ZERO.
       77  W-NO-CTR        PIC 99 VALUE ZERO.
       77  R-NO-CTR        PIC 999 VALUE ZERO.
       77  ANS-1           PIC S99V9(5) COMP-3 VALUE ZERO.
       77  ANS-2           PIC S99V9(5) COMP-3 VALUE ZERO.
       77  BKT-1           PIC S99V9(5) COMP-3 VALUE ZERO.
       77  BKT-2           PIC S99V9(5) COMP-3 VALUE ZERO.
       77  BKT-3           PIC S99V9(5) COMP-3 VALUE ZERO.
       77  BKT-4           PIC S99V9(5) COMP-3 VALUE ZERO.
       77  BKT-5           PIC S99V9(5) COMP-3 VALUE ZERO.
       77  BKT-E           PIC S99V9(5) COMP-3 VALUE ZERO.
000095 77  BKT-X           PIC S99V9(5) COMP-3 VALUE ZERO.
       77  PRINT-BKT       PIC S999 COMP-3 VALUE ZERO.
       77  PRINT-E         PIC S999 COMP-3 VALUE ZERO.
       77  NO-OF-M         PIC 99 VALUE ZERO.
       77  NO-OF-V         PIC 99 VALUE ZERO.
       77  NO-OF-S         PIC 99 VALUE ZERO.
000107 77  V-NOA           PIC 99 VALUE ZERO.
000108 77  XX              PIC S9(4) COMP.
000110 77  YY              PIC S9(4) COMP.
000111 77  ZZ              PIC S9(4) COMP.
000112 77  C-MEAS          PIC S9(4) COMP.
000114 77  SW-MASK         PIC 9 VALUE ZERO.
       01  CARD-WORK.
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                03  CARD-NO      PIC 99
000117          03  CARD-NO-X REDEFINES CARD-NO PIC XX.
                03  CARD-TYPE    PIC X
                03  VESS-NAME    PIC X(77).
                03  SYSTEM-CARD REDEFINES VESS-NAME.
                    05  FILLER       PIC XXX.
000130              05  SYST-SHORT   PIC X(28).
000172              05  FILLER       PIC X(46).
                03  MEASURE-CARD REDEFINES SYSTEM-CARD.
                    05  MEAS-NGT     PIC XXX.
                    05  MEAS-NGT-N REDEFINES MEAS-NGT   PIC 999.
                    05  MEAS-SHORT   PIC X(10).
000141              05  MEAS-SHORTA PIC X(10).
000142              05  FILLER       PIC X(54).
                03  NUMBER-CARD REDEFINES MEASURE-CARD.
                    05  FILLER       PIC X(5).
                    05  NC-V         PIC 99.
                    05  FILLER       PIC X.
                    05  NC-S         PIC 99.
                    05  FILLER       PIC X(67).
000151  01  MASK-WORK.
                03  MASK-VES-NO      PIC 99.
                03  MASK-CARD-TYPE   PIC X.
                03  MASK-DETAIL OCCURS 26 TIMES.
                    05  MD-SYS       PIC 99.
                    05  FILLER       PIC X.
        01  HEAD-1.
000152          03  FILLER  PIC X(7) VALUE SPACES.
000153          03  H-DATE  PIC X(8).
                03  FILLER  PIC X(19) VALUE SPACES.
                03  FILLER  PIC X(27) VALUE 'EFFECTIVENESS OF CANDIDATE '.
000184          03  FILLER  PIC X(22) VALUE 'WASTEWATER MANAGEMENT '.
000198          03  FILLER  PIC X(20) VALUE SPACES.
                03  FILLER  PIC X(5)  VALUE 'PAGE '.
                03  H-PAGE  PIC 29.
                03  FILLER  PIC X(27) VALUE SPACES.
        01  HEAD-2.
000156          03  FILLER  PIC X(34) VALUE SPACES.
                03  FILLER  PIC X(27) VALUE 'SYSTEMS FOR SELECTED COAST '.
                03  FILLER  PIC X(13) VALUE 'GUARD VESSELS'.
000202          03  FILLER  PIC X(56) VALUE SPACES.
        01  HEAD-3.
                03  FILLER  PIC X(37) VALUE SPACES.
                03  FILLER  PIC X(8)  VALUE 'VESSEL  '.
                03  H3-NAME PIC X(30) VALUE SPACES.
                03  FILLER  PIC X(18) VALUE SPACES.
000213  01  H-3-UNDER.
                03  FILLER  PIC X(37) VALUE SPACES.
                03  FILLER  PIC X(6)  VALUE '------'.
                03  FILLER  PIC X(90) VALUE SPACES.
        01  HEAD-4.
000210          03  FILLER  PIC X(31) VALUE SPACES.
000218          03  FILLER  PIC X(26) VALUE '* * * * * * MEASURE OF E'.
000220          03  FILLER  PIC X(25) VALUE 'FFECTIVENESS (AND ASSOCI'.
000222          03  FILLER  PIC X(26) VALUE 'ATED WEIGHT)  * * * * * *'.
000218          03  FILLER  PIC X(25) VALUE SPACES.
        01  HEAD-5.
000222          03  FILLER  PIC X(31) VALUE SPACES.
000223          03  H5-NO1  PIC X(11) VALUE SPACES.
                03  H5-NO2  PIC X(11) VALUE SPACES.
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                03  H5-NO3   PIC X(11) VALUE SPACES.
                03  H5-NO4   PIC X(11) VALUE SPACES.
                03  H5-NO5   PIC X(11) VALUE SPACES.
                03  H5-NO6   PIC X(11) VALUE SPACES.
                03  H5-NO7   PIC X(11) VALUE SPACES.
000224          03  FILLER   PIC X(14) VALUE '      OVERALL'.
000226          03  FILLER   PIC X(11) VALUE SPACES.
          01  HEAD-6.
                03  FILLER   PIC X(15) VALUE '    SYSTEM
000231          03  FILLER   PIC X(16) VALUE SPACES.
                03  H6-NO1   PIC X(11) VALUE SPACES.
                03  H6-NO2   PIC X(11) VALUE SPACES.
                03  H6-NO3   PIC X(11) VALUE SPACES.
                03  H6-NO4   PIC X(11) VALUE SPACES.
                03  H6-NO5   PIC X(11) VALUE SPACES.
                03  H6-NO6   PIC X(11) VALUE SPACES.
                03  H6-NO7   PIC X(11) VALUE SPACES.
                03  FILLER   PIC X(17) VALUE '    EFFECTIVENESS'.
000248          03  FILLER   PIC X(8)  VALUE SPACES.
          01  HEAD-7.
000252          03  FILLER   PIC X(10) VALUE '   NO. NAME      '.
000253          03  FILLER   PIC X(16) VALUE '                (1'.
                03  H7-W1    PIC ZZ9.
                03  FILLER   PIC X(8)  VALUE ')      (1'.
                03  H7-W2    PIC ZZ9.
                03  FILLER   PIC X(8)  VALUE ')      (1'.
                03  H7-W3    PIC ZZ9.
                03  FILLER   PIC X(8)  VALUE ')      (1'.
                03  H7-W4    PIC ZZ9.
                03  FILLER   PIC X(8)  VALUE ')      (1'.
                03  H7-W5    PIC ZZ9.
                03  FILLER   PIC X(8)  VALUE ')      (1'.
                03  H7-W6    PIC ZZ9.
                03  FILLER   PIC X(8)  VALUE ')      (1'.
                03  H7-W7    PIC ZZ9.
                03  FILLER   PIC X(16) VALUE ')          ( E )'.
000282          03  FILLER   PIC X(12) VALUE SPACES.
          01  UNDER-LINE.
000286          03  FILLER   PIC X(26) VALUE '  ------------------------'.
000288          03  FILLER   PIC X(28) VALUE '  ---------  ---------  ---'.
000290          03  FILLER   PIC X(28) VALUE '-----   ---------  --------'.
000292          03  FILLER   PIC X(28) VALUE '  ---------  ----------    '.
000293          03  FILLER   PIC X(14) VALUE '--------------'.
000294          03  FILLER   PIC X(7)  VALUE SPACES.
          01  DETAIL-LINE.
                03  FILLER   PIC XX.
000300          03  DET-SYS  PIC X(20).
                03  DET-M1   PIC ZZZZZZ9.
                03  DET-M2   PIC ZZZZZZZZZZ9.
                03  DET-M3   PIC ZZZZZZZZZZ9.
                03  DET-M4   PIC ZZZZZZZZZZ9.
                03  DET-M5   PIC ZZZZZZZZZZ9.
                03  DET-M6   PIC ZZZZZZZZZZ9.
                03  DET-M7   PIC ZZZZZZZZZZ9.
                03  FILLER   PIC X(13)
                03  DET-DE   PIC ZZZ9.
000320          03  FILLER   PIC X(13).
000305 01  MASK-LINE.
                03  FILLER   PIC XX.
000326          03  ML-SYS   PIC X(20).
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           03  FILLER   PIC X(4).
           03  ML-1     PIC XXX.
           03  FILLER   PIC X(8).
           03  ML-2     PIC XXX.
           03  FILLER   PIC X(8).
           03  ML-3     PIC XXX.
           03  FILLER   PIC X(8).
           03  ML-4     PIC XXX.
           03  FILLER   PIC X(8).
           03  ML-5     PIC XXX.
           03  FILLER   PIC X(8).
           03  ML-6     PIC XXX.
           03  FILLER   PIC X(8).
           03  ML-7     PIC XXX.
           03  FILLER   PIC X(14).
           03  ML-DE    PIC XXX.
000360     03  FILLER   PIC X(13).
       01  MEAS-TABLE.
           03  M-TABLE OCCURS 15 TIMES.
               05  MT-MGT   PIC 999.
               05  MT-NAME  PIC X(10).
000365         05  MT-NMA   PIC X(10).
       01  SYST-TABLE.
000316     03  S-TABLE OCCURS 30 TIMES.
               05  ST-NO    PIC 99.
000376         05  ST-NAME  PIC X(28).
       01  VESS-TABLE.
           03  V-TABLE OCCURS 20 TIMES.
               05  VT-NO    PIC 99.
               05  VT-NAME  PIC X(30).
       01  RTG-TABLE.
           03  R-TABLE OCCURS 7 TIMES.
               05  R-FACTOR OCCURS 180 TIMES.
                   07  RTG-CODE     PIC 9(5).
000393             07  RTG-SHIP-NO  PIC 99.
000394             07  RTG-FACT     PIC S999 COMP-3 OCCURS 30 TIMES.
       01  WGT-TABLE.
           03  W-TABLE OCCURS 7 TIMES.
               05  W-FACTOR OCCURS 75 TIMES.
                   07  WGT-CODE     PIC 9(5).
000404             07  WGT-FACT     PIC S999 COMP-3 OCCURS 20 TIMES.
000349 01  MASK-TABLE.
           03  TABLE-MASK OCCURS 20 TIMES.
               05  MASK-VES     PIC 99.
               05  MASK-SYS     PIC 99 OCCURS 26 TIMES.
       01  F-WORK.
           03  FW-MEAS-NO   PIC 99.
           03  FW-TYPE      PIC X.
           03  FW-CODE      PIC 9(5).
           03  FW-CODE-X REDEFINES FW-CODE PIC X(5).
000424     03  FILLER       PIC X(29).
000425     03  FW-SHIP      PIC 99.
           03  FW-DUP       PIC X.
000428     03  FW-DETAIL OCCURS 10 TIMES.
000430         05  FW-FACT      PIC 999.
000432         05  CONT-CODE    PIC X.
       PROCEDURE DIVISION.
000359     ACCEPT M-DATE.
           OPEN INPUT FACTOR-FILE.
           OPEN OUTPUT PRINT-FILE.
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                PERFORM CLEAR-MEAS-TABLE VARYING M-CTR FROM 1 BY 1
                    UNTIL M-CTR GREATER THAN 15.
                PERFORM CLEAR-SYST-TABLE VARYING S-CTR FROM 1 BY 1
000448              UNTIL S-CTR GREATER THAN 30.
                PERFORM CLEAR-VESS-TABLE VARYING V-CTR FROM 1 BY 1
                    UNTIL V-CTR GREATER THAN 20.
                PERFORM CLEAR-RTG-WGT-TABLE.
                GO TO READ-FACTORS.
            CLEAR-MEAS-TABLE.
                MOVE ZEROS TO MT-WGT (M-CTR).
                MOVE SPACES TO MT-NAME (M-CTR).
            CLEAR-SYST-TABLE.
                MOVE ZEROS TO ST-NO (S-CTR).
                MOVE SPACES TO ST-NAME (S-CTR).
            CLEAR-VESS-TABLE.
                MOVE ZEROS TO VT-NO (V-CTR).
                MOVE SPACES TO VT-NAME (V-CTR).
            MEAS-CARD-RTN.
                EXAMINE MEAS-WGT REPLACING ALL SPACES BY ZEROS.
000423          EXAMINE CARD-NO-X REPLACING ALL SPACES BY ZEROS.
                IF MEAS-WGT-N NOT NUMERIC
                    DISPLAY 'WEIGHT NOT NUMERIC ON MEASURE CARD'
                    DISPLAY 'RUN ABORTED'
000496              GO TO EOJ.
                IF MEAS-WGT-N GREATER THAN 100
                    DISPLAY 'INVALID MEASURE WEIGHT'
                    DISPLAY 'RUN ABORTED'
000504              GO TO EOJ.
                IF MEAS-WGT-N LESS THAN ZERO
                    DISPLAY 'INVALID MEASURE WEIGHT'
                    DISPLAY 'RUN ABORTED'
000512              GO TO EOJ.
                IF CARD-NO GREATER THAN 15
                    DISPLAY 'MEASURE NUMBER INVALID'
                    DISPLAY 'RUN ABORTED'
000520              GO TO EOJ.
                MOVE MEAS-WGT-N TO MT-WGT (CARD-NO).
                MOVE MEAS-SHORT TO MT-NAME (CARD-NO).
000525          MOVE MEAS-SHORTA TO MT-NMA (CARD-NO).
                ADD MEAS-WGT-N TO MEAS-WGT-SUM.
                ADD 1 TO NO-OF-M.
                GO TO READ-FACTORS.
            SYST-CARD-RTN.
000468          IF CARD-NO GREATER THAN 30
                    DISPLAY 'SYSTEM NUMBER INVALID'
                    DISPLAY 'RUN ABORTED'
000540              GO TO EOJ.
000475          IF CARD-NO LESS THAN ZERO
                    DISPLAY 'SYSTEM NUMBER INVALID'
                    DISPLAY 'RUN ABORTED'
000548              GO TO EOJ.
                MOVE CARD-NO TO ST-NO (CARD-NO).
                MOVE SYST-SHORT TO ST-NAME (CARD-NO).
                GO TO READ-FACTORS.
            VESS-CARD-RTN.
                IF CARD-NO GREATER THAN 20
                    DISPLAY 'VESSEL NUMBER INVALID'
                    DISPLAY 'JOB ABORTED'
000564              GO TO EOJ.
000451          IF CARD-NO LESS THAN ZERO
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                DISPLAY 'VESSEL NUMBER INVALID'
                DISPLAY 'JOB ABORTED'
000572          GO TO EOJ.
           MOVE CARD-NO TO VT-NO (CARD-NO).
           MOVE VESS-NAME TO VT-NAME (CARD-NO).
           GO TO READ-FACTORS.
000497 MASK-CARD-RTN.
           MOVE CARD-WORK TO MASK-WORK.
           PERFORM BUILD-MASK VARYING YY FROM 1 BY 1 UNTIL
               YY GREATER THAN 26.
           MOVE MASK-VES-NO TO MASK-VES (MASK-VES-NO).
           GO TO READ-FACTORS.
       BUILD-MASK.
           IF MD-SYS (YY) NOT EQUAL SPACES
               MOVE MD-SYS (YY) TO MASK-SYS (MASK-VES-NO,YY).
       END-OF-CARDS.
           MOVE MT-WGT (1) TO H7-W1.
000602     MOVE MT-NAME (1) TO H5-NO1.
000603     MOVE  MT-NMA (1) TO H6-NO1.
           MOVE MT-WGT (2) TO H7-W2.
000606     MOVE MT-NAME (2) TO H5-NO2.
000607     MOVE  MT-NMA (2) TO H6-NO2.
           MOVE MT-WGT (3) TO H7-W3.
000610     MOVE MT-NAME (3) TO H5-NO3.
000611     MOVE  MT-NMA (3) TO H6-NO3.
           MOVE MT-WGT (4) TO H7-W4.
000614     MOVE MT-NAME (4) TO H5-NO4.
000615     MOVE  MT-NMA (4) TO H6-NO4.
           MOVE MT-WGT (5) TO H7-W5.
000618     MOVE MT-NAME (5) TO H5-NO5.
000619     MOVE  MT-NMA (5) TO H6-NO5.
           MOVE MT-WGT (6) TO H7-W6.
000622     MOVE MT-NAME (6) TO H5-NO6.
000623     MOVE  MT-NMA (6) TO H6-NO6.
           MOVE MT-WGT (7) TO H7-W7.
000626     MOVE MT-NAME (7) TO H5-NO7.
000627     MOVE  MT-NMA (7) TO H6-NO7.
       CLEAR-RTG-WGT-TABLE.
           MOVE ALL '0' TO RTG-TABLE.
           MOVE ALL '0' TO WGT-TABLE.
000533     MOVE ALL '0' TO MASK-TABLE.
       READ-FACTORS.
           READ FACTOR-FILE INTO F-WORK AT END GO TO TABLES-BUILT.
           IF FW-TYPE = 'R' GO TO FACTOR-R-RTN.
           IF FW-TYPE = 'W' GO TO FACTOR-W-RTN.
           MOVE F-WORK TO CARD-WORK.
           IF FW-TYPE = 'M' GO TO MEAS-CARD-RTN.
           IF FW-TYPE = 'S' GO TO SYST-CARD-RTN.
           IF FW-TYPE = 'V' GO TO VESS-CARD-RTN.
000549     IF FW-TYPE = 'K' GO TO MASK-CARD-RTN.
           IF FW-TYPE = 'N'
               MOVE NC-V TO NO-OF-V
               MOVE NC-S TO NO-OF-S
               GO TO READ-FACTORS.
000558     DISPLAY 'INVALID CARD TYPE'.
           DISPLAY 'RUN ABORTED'.
000666         GO TO EOJ.
       FACTOR-R-RTN.
           IF SAVE-R-MEAS EQUAL ZERO
               MOVE ZERO TO XX
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                MOVE FW-MEAS-NO TO SAVE-R-MEAS.
              IF FW-MEAS-NO NOT EQUAL TO SAVE-R-MEAS
                MOVE ZERO TO XX
                MOVE FW-MEAS-NO TO SAVE-R-MEAS.
000682        IF CONT-CODE (10) LESS THAN '2' ADD 1 TO XX.
              MOVE FW-MEAS-NO TO C-MEAS.
              EXAMINE FW-CODE-X REPLACING ALL SPACES BY ZEROS.
              MOVE FW-CODE TO RTG-CODE (C-MEAS,XX).
000738        IF FW-SHIP NOT NUMERIC MOVE ZEROS TO RTG-SHIP-NO (C-MEAS,XX)
                ELSE
                MOVE FW-SHIP TO RTG-SHIP-NO (C-MEAS,XX).
000736        IF CONT-CODE (10) = '3'
                COMPUTE V-NOA = NO-OF-S - 20
                PERFORM BUILD-R3 VARYING YY FROM 1 BY 1 UNTIL
                  YY GREATER THAN V-NOA
                GO TO READ-FACTORS.
              IF CONT-CODE (10) = '2'
                GO TO FACTOR-R-2.
              IF CONT-CODE (10) = '1'
                PERFORM BUILD-R-TABLE VARYING YY FROM 1 BY 1 UNTIL
                  YY GREATER THAN 10
                GO TO READ-FACTORS.
              PERFORM BUILD-R-TABLE VARYING YY FROM 1 BY 1 UNTIL
                YY GREATER THAN NO-OF-S.
              GO TO READ-FACTORS.
000655 FACTOR-R-2.
              IF NO-OF-S GREATER THAN 19
                MOVE 10 TO V-NOA
                ELSE
                COMPUTE V-NOA = NO-OF-S - 10.
              PERFORM BUILD-R2 VARYING YY FROM 1 BY 1 UNTIL
                YY GREATER THAN V-NOA.
              GO TO READ-FACTORS.
            BUILD-R-TABLE.
              MOVE FW-FACT (YY) TO RTG-FACT (C-MEAS,XX,YY).
000699 BUILD-R3.
              COMPUTE ZZ = YY + 20.
              MOVE FW-FACT (YY) TO RTG-FACT (C-MEAS,XX,ZZ).
            BUILD-R2.
              COMPUTE ZZ = YY + 10.
              MOVE FW-FACT (YY) TO RTG-FACT (C-MEAS,XX,ZZ).
            FACTOR-W-RTN.
              IF SAVE-W-MEAS EQUAL ZERO
                MOVE ZERO TO XX
                MOVE FW-MEAS-NO TO SAVE-W-MEAS.
              IF FW-MEAS-NO NOT EQUAL TO SAVE-W-MEAS
                MOVE ZERO TO XX
                MOVE FW-MEAS-NO TO SAVE-W-MEAS.
000714        IF CONT-CODE (10) LESS THAN '2' ADD 1 TO XX.
              MOVE FW-MEAS-NO TO C-MEAS.
              EXAMINE FW-CODE-X REPLACING ALL SPACES BY ZEROS.
              MOVE FW-CODE TO RGT-CODE (C-MEAS,XX).
              IF FW-DUP = 'X'
000724          PERFORM BUILD-W-DUP VARYING YY FROM 1 BY 1 UNTIL
000726          YY GREATER THAN NO-OF-W
000727          GO TO READ-FACTORS.
              IF CONT-CODE (10) = '2'
                COMPUTE V-NOA = NO-OF-W - 10
000830          PERFORM BUILD-W2 VARYING YY FROM 1 BY 1 UNTIL
                  YY GREATER THAN V-NOA
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                GO TO READ-FACTORS.
            IF CONT-CODE (10) = '1'
                PERFORM BUILD-W-TABLE VARYING YY FROM 1 BY 1 UNTIL
                  YY GREATER THAN 10
                GO TO READ-FACTORS.
            PERFORM BUILD-W-TABLE VARYING YY FROM 1 BY 1 UNTIL
                YY GREATER THAN NO-OF-V.
            GO TO READ-FACTORS.
        BUILD-W-TABLE.
            MOVE FW-FACT (YY) TO WGT-FACT (C-MEAS,XX,YY).
  000741 BUILD-W-DUP.
            MOVE FW-FACT (1) TO WGT-FACT (C-MEAS,XX,YY).
        BUILD-W2.
            COMPUTE ZZ = YY + 10.
            MOVE FW-FACT (YY) TO WGT-FACT (C-MEAS,XX,ZZ).
        TABLES-BUILT.
            PERFORM END-OF-CARDS.
  000746    MOVE ZEROS TO XX, YY, ZZ, C-MEAS,
                          SAVE-R-MEAS,
                          SAVE-W-MEAS,
                          M-CTR, S-CTR, V-CTR.
            PERFORM HEADING-RTN THRU H-EXIT.
            IF MEAS-WGT-SUM NOT EQUAL 100
                DISPLAY 'MEASURES DO NOT TOTAL 100'
                DISPLAY 'RUN ABORTED'
  000764        GO TO EOJ.
        TEST-V-CTR.
            IF V-CTR GREATER THAN NO-OF-V GO TO EOJ.
            IF S-CTR EQUAL NO-OF-S
                PERFORM HEADING-RTN THRU H-EXIT
                MOVE ZERO TO S-CTR M-CTR
                GO TO TEST-V-CTR.
            ADD 1 TO S-CTR.
        TEST-M-CTR.
            IF M-CTR EQUAL NO-OF-M
                PERFORM CALCULATE-E
                MOVE ZERO TO M-CTR
                GO TO TEST-V-CTR.
            ADD 1 TO M-CTR.
        CALC-RESULTS.
            ADD 1 TO W-NO-CTR.
            IF W-CODE-HOLD = SPACES MOVE WGT-CODE (M-CTR,W-NO-CTR)
                TO W-CODE-HOLD.
            EXAMINE WGT-CODE (M-CTR,W-NO-CTR) TALLYING ALL ZEROS.
            MOVE TALLY TO WGT-CODE-TALLY.
            EXAMINE W-CODE-HOLD TALLYING ALL ZEROS.
            MOVE TALLY TO WGT-HOLD-TALLY.
            IF WGT-CODE-TALLY GREATER THAN WGT-HOLD-TALLY
                GO TO CHANGE-LEVEL.
            MOVE WGT-CODE (M-CTR,W-NO-CTR) TO W-CODE-HOLD.
  000813 R-NO-MATCH.
            ADD 1 TO R-NO-CTR.
  000815    IF RTG-CODE (M-CTR,R-NO-CTR) GREATER THAN
                WGT-CODE (M-CTR,W-NO-CTR) GO TO R-NO-MATCH.
            IF RTG-SHIP-NO (M-CTR,R-NO-CTR) = ZERO
                GO TO RW-MATCH.
            IF RTG-SHIP-NO (M-CTR,R-NO-CTR) = V-CTR
                GO TO RW-MATCH.
            GO TO R-NO-MATCH.
  000853 RW-MATCH.
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            COMPUTE ANS-1 = WGT-FACT (M-CTR,W-NO-CTR,V-CTR) *
000700                              RTG-FACT (M-CTR,R-NO-CTR,S-CTR) / 10000.
            IF WGT-CODE-TALLY = 0
                ADD ANS-1 TO BKT-1.
            IF WGT-CODE-TALLY = 1
                ADD ANS-1 TO BKT-2.
            IF WGT-CODE-TALLY = 2
                ADD ANS-1 TO BKT-3.
            IF WGT-CODE-TALLY = 3
                ADD ANS-1 TO BKT-4.
            IF WGT-CODE-TALLY = 4
                ADD ANS-1 TO BKT-5.
            IF WGT-CODE (M-CTR,W-NO-CTR) = '10000' GO TO END-OF-W.
            GO TO CALC-RESULTS.
        CHANGE-LEVEL.
            IF WGT-CODE-TALLY = 1
000748          COMPUTE ANS-2 =
                    WGT-FACT (M-CTR,W-NO-CTR,V-CTR) * BKT-1 / 100
                COMPUTE BKT-2 = BKT-2 + ANS-2
                MOVE ZEROS TO BKT-1.
            IF WGT-CODE-TALLY = 2
000756          COMPUTE ANS-2 =
                    WGT-FACT (M-CTR,W-NO-CTR,V-CTR) * BKT-2 / 100
                COMPUTE BKT-3 = BKT-3 + ANS-2
                MOVE ZEROS TO BKT-2.
            IF WGT-CODE-TALLY = 3
000764          COMPUTE ANS-2 =
                    WGT-FACT (M-CTR,W-NO-CTR,V-CTR) * BKT-3 / 100
                COMPUTE BKT-4 = BKT-4 + ANS-2
                MOVE ZEROS TO BKT-3.
            IF WGT-CODE-TALLY = 4
000772          COMPUTE ANS-2 =
                    WGT-FACT (M-CTR,W-NO-CTR,V-CTR) * BKT-4 / 100
                COMPUTE BKT-5 = BKT-5 + ANS-2
                MOVE ZEROS TO BKT-4.
            MOVE WGT-CODE (M-CTR,W-NO-CTR) TO W-CODE-HOLD.
            IF WGT-CODE (M-CTR,W-NO-CTR) = '10000' GO TO END-OF-W.
            GO TO CALC-RESULTS.
        END-OF-W.
000756      COMPUTE BKT-X = BKT-5 * PT-WGT (M-CTR) / 100.
            ADD BKT-X TO BKT-6.
            COMPUTE PRINT-BKT ROUNDED = BKT-5 * 100.
            MOVE ZEROS TO BKT-5.
            IF M-CTR = 1
                MOVE PRINT-BKT TO DET-M1.
            IF M-CTR = 2
                MOVE PRINT-BKT TO DET-M2.
            IF M-CTR = 3
                MOVE PRINT-BKT TO DET-M3.
            IF M-CTR = 4
                MOVE PRINT-BKT TO DET-M4.
            IF M-CTR = 5
                MOVE PRINT-BKT TO DET-M5.
            IF M-CTR = 6
                MOVE PRINT-BKT TO DET-M6.
            IF M-CTR = 7
                MOVE PRINT-BKT TO DET-M7.
            MOVE ZEROS TO W-NO-CTR
                          R-NO-CTR.
            MOVE SPACES TO W-CODE-HOLD.
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                GO TO TEST-H-CTR.
            CALCULATE-E.
                COMPUTE PRINT-E ROUNDED = EXT-E * 100.
                MOVE ZEROS TO EXT-E.
                MOVE PRINT-E TO DET-DE.
                MOVE ST-NAME (S-CTR) TO DET-SYS.
  000843        PERFORM CHECK-MASK THRU CM-EXIT.
                WRITE P-LINE FROM DETAIL-LINE AFTER POSITIONING 2 LINES.
                MOVE SPACES TO DETAIL-LINE.
                MOVE SPACES TO H-CODE-HOLD.
            HEADING-RTN.
                ADD 1 TO V-CTR.
                IF V-CTR GREATER THAN NO-OF-V GO TO H-EXIT.
                MOVE VT-NAME (V-CTR) TO H3-NAME.
  000823        ADD 1 TO PG-CTR.
                MOVE PG-CTR TO H-PAGE.
                WRITE P-LINE FROM HEAD-1 AFTER POSITIONING 0 LINES.
                WRITE P-LINE FROM HEAD-2 AFTER POSITIONING 1 LINES.
                WRITE P-LINE FROM HEAD-3 AFTER POSITIONING 3 LINES.
  001113        WRITE P-LINE FROM H-3-UNDER AFTER POSITIONING 1 LINES.
                WRITE P-LINE FROM HEAD-4 AFTER POSITIONING 3 LINES.
  000976        WRITE P-LINE FROM HEAD-5 AFTER POSITIONING 2 LINES.
                WRITE P-LINE FROM HEAD-6 AFTER POSITIONING 1 LINES.
                WRITE P-LINE FROM HEAD-7 AFTER POSITIONING 1 LINES.
                WRITE P-LINE FROM UNDER-LINE AFTER POSITIONING 1 LINES.
            H-EXIT.
                EXIT.
  000881    CHECK-MASK.
                PERFORM TEST-MASK VARYING YY FROM 1 BY 1 UNTIL
                    YY GREATER THAN 26.
                IF SW-MASK NOT EQUAL 1 GO TO CM-EXIT.
                MOVE ZERO TO SW-MASK.
                MOVE SPACES TO MASK-LINE.
                MOVE ST-NAME (S-CTR) TO ML-SYS.
                MOVE 'N/A' TO ML-1, ML-2, ML-3, ML-4,
                              ML-5, ML-6, ML-7, ML-DE.
                MOVE MASK-LINE TO DETAIL-LINE.
            CM-EXIT.
                EXIT.
            TEST-MASK.
                IF MASK-SYS (V-CTR,YY) = S-CTR
                    MOVE 1 TO SW-MASK.
            EOJ.
                CLOSE FACTOR-FILE
                      PRINT-FILE.
                STOP RUN.
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